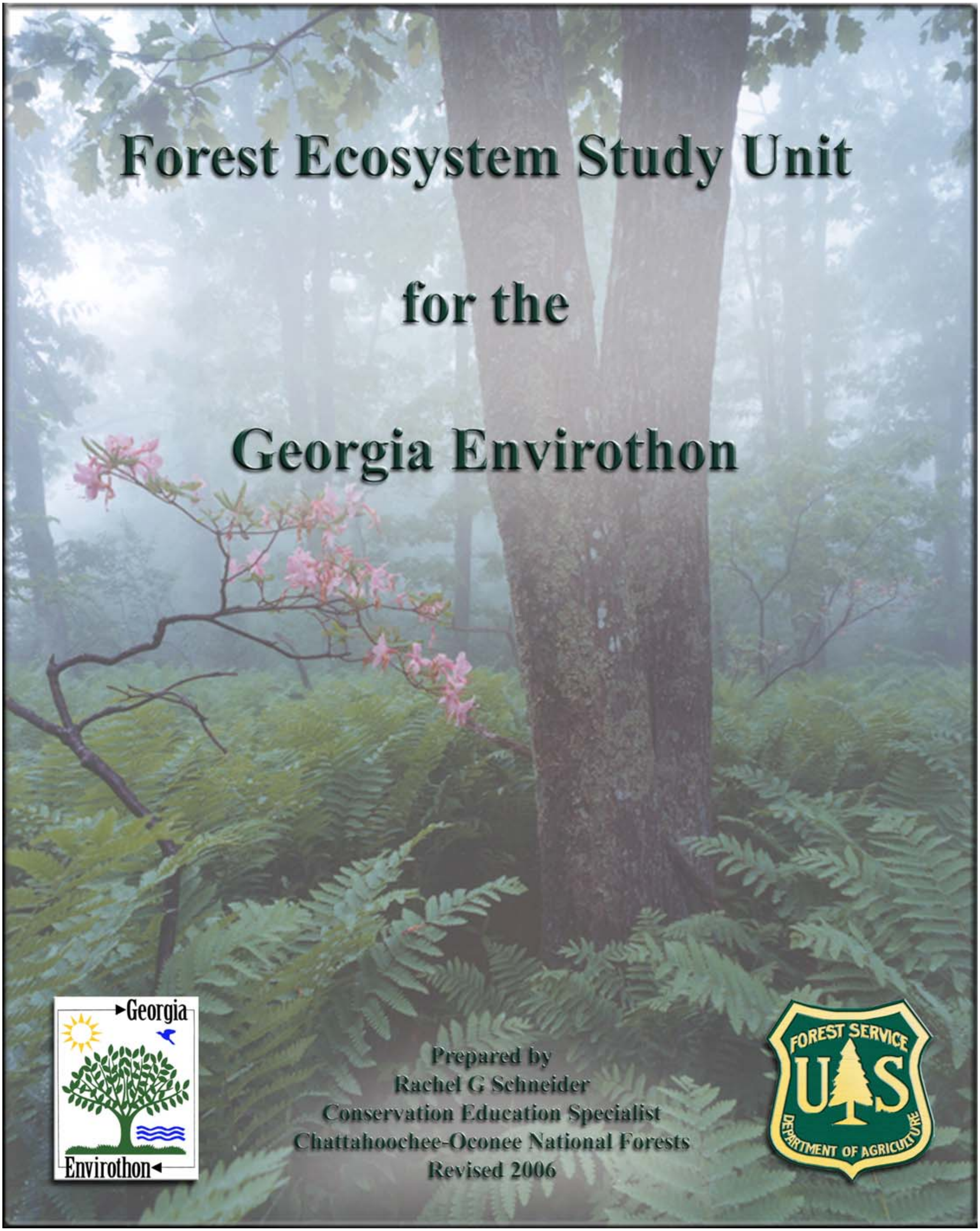

Forest Ecosystem Study Unit

for the

Georgia Envirothon

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Forest Ecosystems

Overview

Georgia has a great diversity of forest ecosystems. Much of this is due to the variation in climate, elevation, soil types and water within the state. Human use of the land is also a big factor influencing the ecosystems existing here. Urban ecosystems, with their great expanse of paved areas, influence water runoff, heat absorption, vegetation present, etc. If humans did not build cities, farm, fertilize, irrigate, use herbicides, burn, mow or otherwise alter the natural environment, then natural regeneration would produce forest ecosystems on the land.

Georgia has 14 congressionally designated wildernesses where nature is allowed to take its course with little or no influence from people. These areas not only preserve the wild character of the land, but offer an outdoor laboratory to study natural changes on the land. Most of these wildernesses are located on the Chattahoochee National Forest in north Georgia. In addition, Georgia has over 800,000 acres of national forests and nearly 24 million acres of productive forestland. Most of the commercial forests are located in middle and south Georgia. These forests have used the multiple-use sustained-yield model for years but are moving away from the sustained yield of timber and following the public forest lead to sustaining forest health, biological diversity, ecological processes, and other values including aesthetics. This ecosystem based approach implies a new level of cooperation by various land owners who may have different management objectives, and who collectively seek many uses from the forests.

Balancing the conservation and development of natural resources is a tremendous task. It begins with an understanding of just what is an ecosystem, how it functions and changes.

Ecosystem Structure

Objectives

1. Define an ecosystem
2. Identify living and nonliving components of an ecosystem.
3. Know the hierarchical structure for describing ecosystem scale.
4. Distinguish between physiographic region and ecological regions.
5. Categorize different types of forests.
6. Understand the functions of forests.
7. Know the basic layers comprising a forest

What is an ecosystem?

An ecosystem is a community of living and nonliving components functioning as an interdependent unit. Examples of ecosystems are wetland, prairie, desert, tropical rain forest, coniferous forest, hardwood forest, etc. Ecosystems vary in size, scale, diversity and connections.

All materials in an ecosystem cycle and change over time. Some changes occur as a result of natural cycles such as the carbon and water cycles, or as a result of natural disasters, human migration, urbanization, industrialization, war and other interactions with the environment. Changes that occur over long periods of time such as species adaptation, continental drift, or global warming are difficult to perceive. Ecosystems are connected at various scales and many of the connections are complex and difficult to understand. For example, scientists have observed a thinning of the ozone layer in various locations throughout the planet, but do not have a full understanding of all the contributing causes or the effect it will have on earth's ecosystems.

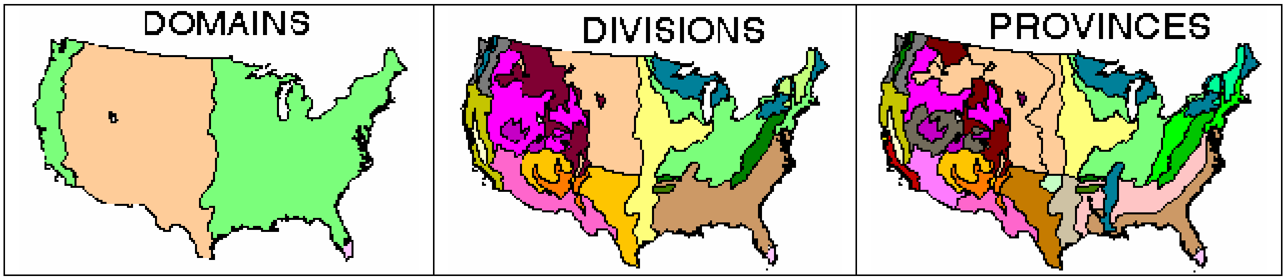
The living and nonliving components of ecosystems can be classified into three general categories. These are the producers, consumers and decomposers. An example of a producer would be a tree. The tree produces some type of fruit or seed. It also gives off oxygen during the photosynthesis process. An example of a consumer would be an animal that eats the fruit or breathes the oxygen. A decomposer would be bacteria in the soil or fungi that breaks down matter. The number, diversity and balance of these components are indicators of ecosystem health. The challenge is to sustain the cycling processes so the ecosystems will continue to provide human and ecological needs for this and future generations.

Ecosystem Classification

The hierarchical structure for broadly describing the scale of ecosystems is domain, division, province and section. The subdivision goes much smaller to allow for specific variations. These classifications are based on observed properties and existing knowledge.

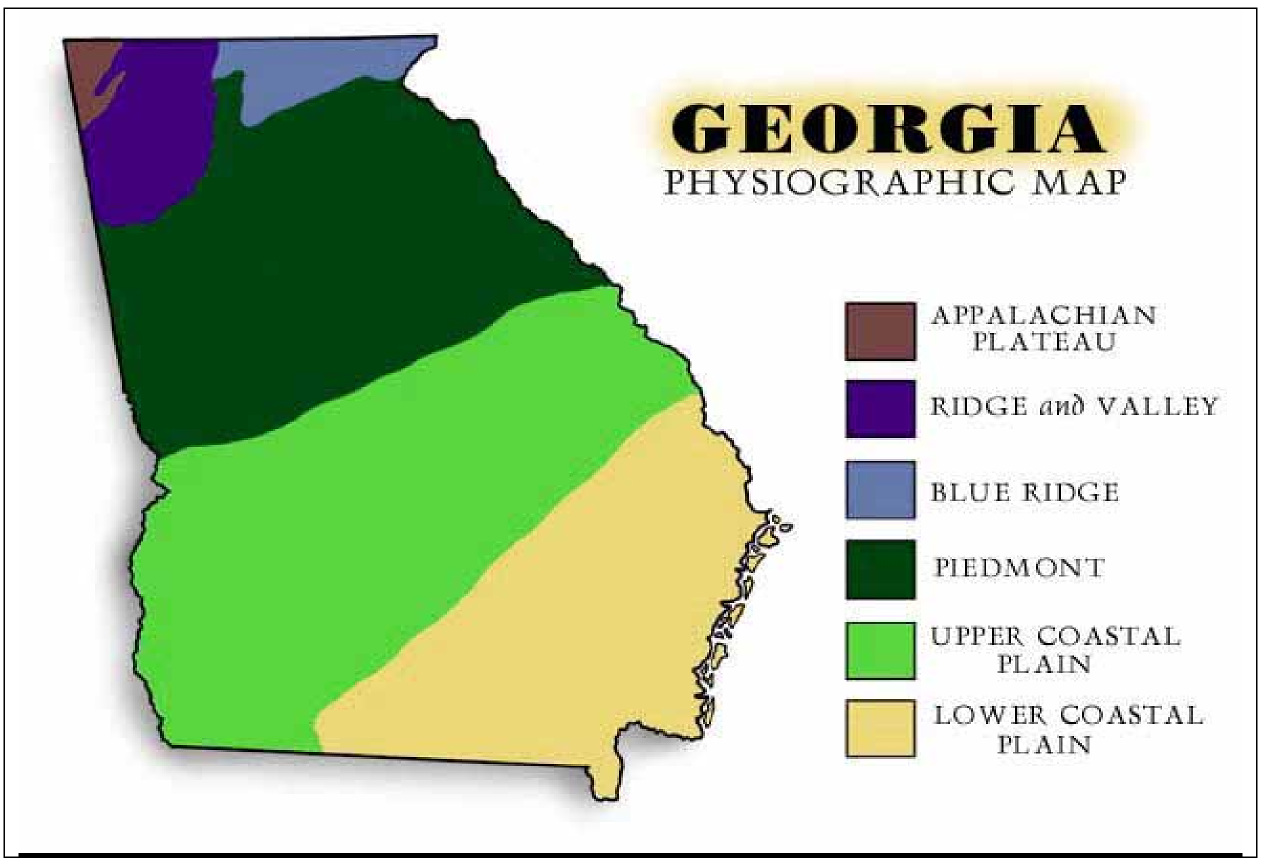
- A domain is a subcontinental area of broad climatic similarity such as lands having dry, wet, cold or warm climates. Georgia is in the subtropical domain also referred to on some maps as the humid temperate domain.
- A division is a subdivision of a domain determined by isolating areas of differing vegetation and regional climates. Usually the zonal soils are related. Georgia is in the hot continental, subtropical and marine divisions.
- A province is a subdivision having uniform regional climate, the same type of zonal soils and a single climax vegetation type. Georgia is in the mountains, piedmont and coastal plain provinces.
- A section is still a smaller unit within a province that reflects climatic nuances within the broad regional climate. Vegetation in a section may be like plants in other biomes. A biome is a large land (terrestrial) ecosystem such as a forest,

grassland or desert as opposed to an aquatic ecosystem (pond, stream, lake, and ocean). Georgia has one ridge and valley section.



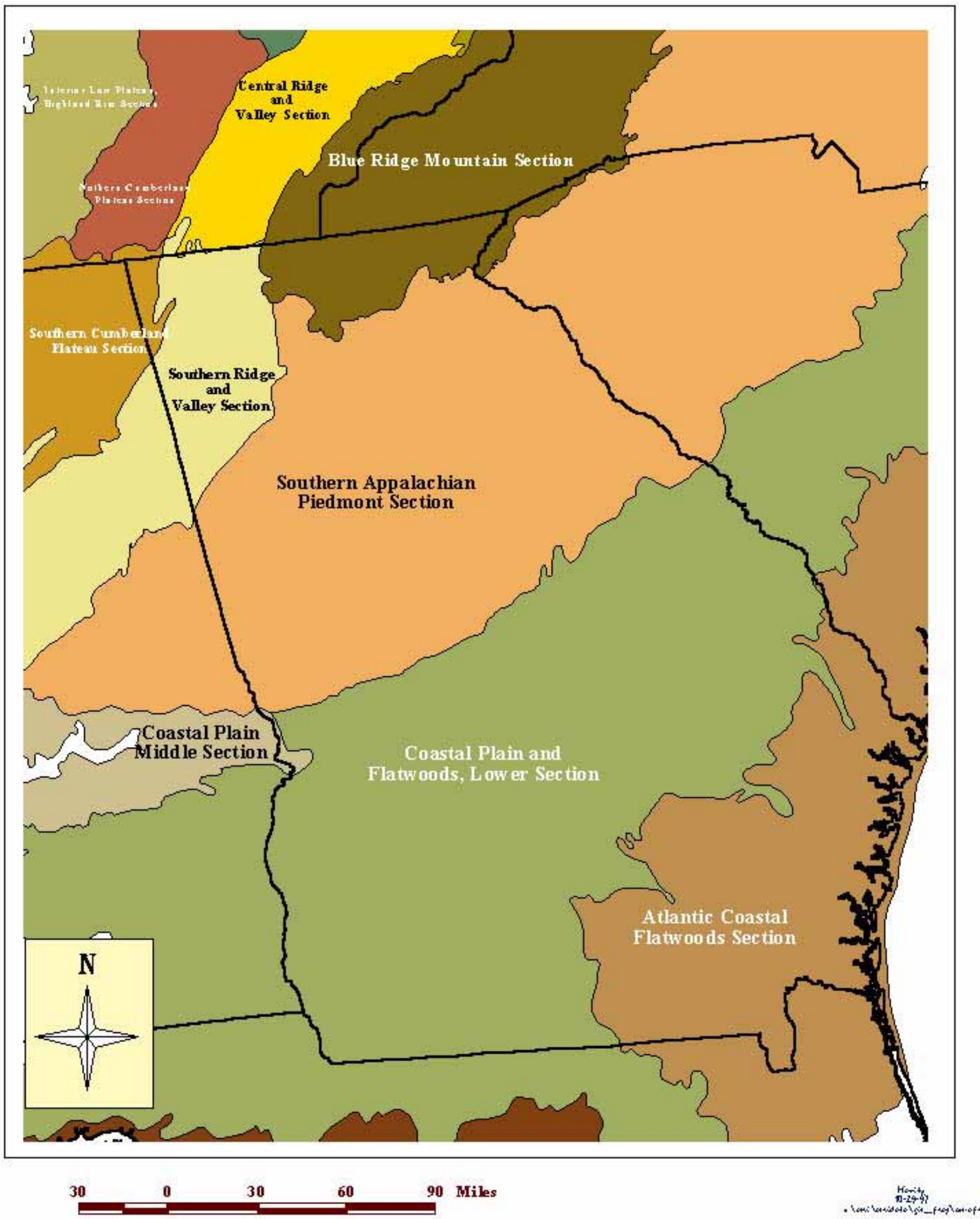
Physiographic regions

The broad physiographic regions of Georgia include the mountains (Appalachian Plateau and the Blue Ridge), piedmont, the upper and lower coastal plains. Physiographic regions are determined by the physical features on the land such as soil types, rocks, minerals, elevation and watersheds. Ecological regions add climate and vegetation types to the picture. Physiographic and ecological regions can and do change over time as evidenced by geological records.



The ecological regions correspond rather closely to the physiographic regions as you can see from the map below. Also refer to the "Forest Type Groups of the United States", a satellite map included in Appendix A and notice how the predominant vegetation changes with the physiographic and ecological regions. You can also access this satellite map on the internet at: http://fia.fs.fed.us/library/maps/ .

Ecological Classification System Sections in Georgia



What is a forest?

Dictionaries define a forest as a large area densely covered with trees. Trees are the largest plants on earth and are producers of food and oxygen in the forest ecosystem. Forests are among the most valuable of the natural resources both for the products they provide and for the intricately woven community of life they host. The community of life includes animals as well as plants that range in size from microorganisms to great oaks and mighty sequoias.

Forests are renewable resources. That is, they will grow back. Nonrenewable natural resources such as oil and minerals will not be replaced by natural processes within a reasonable amount of time. The way humans use the forest greatly impacts its resilience. Each component of the forest community plays a role in continuing the cycle of life, death and rebirth. Some insects pollinate trees while others destroy them by eating leaves and wood. Squirrels eat tons of nuts, bury others that germinate and survive to become mature trees. Some fungi infect living trees and kill them, while other break down dead plant and animal material releasing nutrients to nurture new generations of living things. Deer, bears, birds, beetles, butterflies and many other creatures live in the forest and contribute to its web of life. This intricate web is the forest ecosystem.

The traditional definition of forestry is the science of planting, growing and harvesting trees. Today the production of wood fiber is not the only objective. Forestry is practicing the science in such a manner that the communities of life in a forest will be sustained. This is called ecosystem management.

What are the different kinds of forests?

Broad zones of different types of forests cover much of the earth. Climate, elevation and soil type are the primary factors which determine the climax forest type in an area. The major forest-type zones are:

<u>Coniferous forests</u> are cone-bearing trees with needlelike leaves which do not shed in winter. They are predominately in the colder northern latitudes and portions of the coastal plains but scattered pockets are found throughout the southern United States. Conifers can survive on poorer soil than broadleaf trees. Conifers are generally referred to as softwoods. The wood is valuable for lumber, certain musical instruments, paper, and for resins.

<u>Deciduous forests</u> are the broadleaf trees noted for their brilliant color change in autumn just before the leaves fall. They once covered vast areas of the temperate zone but most were cut down as human populations grew. Most broadleaf trees are considered hardwoods and include oaks, hickories, maples, walnuts, sweetgums, yellow poplars and many other species. They are valuable for fine furniture, lumber, fruits, nuts and saps.

<u>Mixed forests</u> grow where conifers can compete on a more or less equal basis with broadleaf trees. They form a transitional zone between coniferous and deciduous

forests and contain species of both forest types. Some books refer to the northernmost broad band of mixed coniferous and deciduous trees that stretches across northern North America, Europe, and Asia as the Boreal forests.

Tropical rainforests flourish in the tropics where humidity is high and where there is heavy rainfall almost daily. Temperatures are warm with little seasonal variance. Diversity is greatest in the tropical rainforests. Thousands of species of trees thrive here. These forests contribute to the stability of the earth's climate.

Mountain forests may have lush tropical evergreens or wind-twisted conifers depending on the location and climate. Most of these forests are in Alaska, Canada, and the Rocky Mountains; the Appalachian Mountains, Mexico, Central America and the eastern side of the Andes in South America. Siberia, the Himalayas and even eastern Africa have great expanses of these forests. Elevation and temperature identifies this type of forest.

These forest type zones are further classified by the tree species in each zone such as oak-hickory, oak-pine, etc. See the satellite map in Appendix A. The vegetation present influences soil fertility, water and air quality as well as the diversity of wildlife that can be supported in the ecosystem.

Why do we need forests?

Forests are very important to humankind for products, environmental and intangible benefits. Forests are vital parts of the water, nutrient and carbon cycles that support life on the planet. Trees clean the air, moderate temperature, buffer noise, provide wildlife habitat, protect the soil from erosion, regulate water storage and affect water quality. These are functions necessary for our survival.

Air Trees and all green plants, convert water and carbon dioxide into sugars and release oxygen as a by-product through photosynthesis. An acre of trees can give off enough oxygen for 14 people daily. Too much carbon dioxide is considered a pollutant. Through the photosynthesis process, trees "lock" or sequester carbon until the tree dies and decay slowly releases the carbon. An acre of new forest will sequester about 2.5 tons of carbon annually. Trees can absorb CO2 at the rate of 13 pounds/tree/year. Trees reach their most productive stage of carbon storage at about 10 years.

Trees also help manage the amount of particulate matter picked up and carried by the wind. Trees serve as windbreaks that slow the force of wind and prevent topsoil from being blown away. When dust or other particulate matter is picked up by the wind, forests buffer the wind speed so the material can settle back to the ground.

Temperature In the winter, forests buffer winter winds, thus modifying the chill factor. Moisture transpiration in the summer acts as natural air conditioning. An acre of trees with the shade produced can reduce cooling costs up to 30% in 90 degree weather.

A large hardwood tree has the cooling capacity of 800,000 BTU's per day, which is equivalent to 20 window air conditioning units running 20 hours per day.

Noise Trees absorb loud noises thus buffering sound. Sound is measured in decibels. An acre of trees, depending on the species and spacing can reduce noise pollution by 50 percent.

Wildlife Forests provide homes for over 400 species of wildlife and thousands of beneficial micro-organisms in Georgia. Certain tree species provide food such as nuts, berries and fruit that sustain wildlife as well as offering shelter. Many species obtain their water needs from twigs and the fruit of trees.

Soil Forests reduce and control erosion by rainfall and wind. Leaves and needles buffer the velocity of wind and rainfall. The roots and organic litter (dead leaves and needles) protect the soil from being carried away by rain and wind. An acre of trees of any size can conserve up to 100 lbs. of topsoil during a 2-inch rainfall.

Water Trees take up large quantities of water from the soil. Some of it is used in the photosynthesis process and some is used as a solvent to transport minerals and nutrients, but most of it is incorporated in the protoplasm of the tree cells. About 80-90 percent of a tree's weight is water. Roughly 95 percent of the water in a tree is transformed from a liquid into a gas in the transpiration or evaporative process. This is very important to the water cycle. Transpired water is constantly being replaced by water the tree pumps from the soil. When transpiration is occurs faster than water can be taken in from the soil, the tree wilts. Transpiration is greater on hot summer afternoons.

Forests also affect the quality of the water in our lakes and streams. The roots and dead leaves and needles slow runoff from rain and let the water soak into the soil. This also traps certain chemicals from the atmosphere and prevents them from entering lakes and streams. Without this buffering effect, soil can be carried by runoff into streams, adversely affecting stream flow, water quality and aquatic life.

Products The forest products industry has found uses for nearly every part of a tree, so virtually nothing is wasted when a tree is harvested. Commercial trees are used for lumber and veneer if they are larger than 8 inches in diameter and if they are of suitable quality. Larger trees unsuitable for solid wood products can be used to make paper, particle board and a number of other products.

Cellulose and natural wood chemicals are extracted and used to make everything from plastics and food flavorings to photographic film and chewing gum. Bark is useful for producing dyes, adhesives and medicines as well as ground or chipped for garden mulch or burned in furnaces to generate energy. Leaves and needles are used for pine and cedar oil but area generally left in the forest to replenish the soil. Over 5,000 different products we use every day either come from trees or use some by-product of a tree in its manufacture. A partial list of these products is on the next page.

PRODUCTS MADE FROM TREES				
Asphalt	Toothpaste	Paper products	Hairspray	Paint
Charcoal	Printing ink	M&Ms	Eye shadow	Dye
Artificial vanilla	Maple sugar	Flooring	Rayon	Sponge
Ice cream thickeners	Maple syrup	Plywood	Solid alcohol	Fuel
Adhesives	Varnish	Shoe polish	Shingles	Pencils
Shoe heels	Food preservatives	Telephone poles	Sausage casings	Oil
Tool handles	Popsicle sticks	Furniture	Shatterproof glass	Tea
Chewing gum	Cellophane	Photographic film	Artificial hair	Paper

It is obvious we do not go through a single day without using products from trees. Wood is durable, renewable, recyclable, biodegradable, and energy efficient. Nationally, forest product companies are one of the most efficient of all manufacturing industries because they use sawdust and other wood waste to furnish up to 75% of their energy needs. It is very important for everyone to be good stewards of our forest resources.

What are the layers of a forest?

A forest is comprised of four basic layers, each with an important role in the ecosystem.

<u>Emergent layer</u> This layer is made up of the tallest trees that rise above all others. This layer provides habitat for many species of birds to perch and build nests.

<u>Canopy layer</u> This is the upper layer in a forest comprised of branches, leaves, and tree tops. This layer provides habitat for birds, climbing animals and insects. Tree-climbing vines often reach this layer.

<u>Understory layer</u> The understory layer is made up of trees, shrubs, and vines growing beneath the canopy. Sometimes these species are different from the ones that make it to the canopy and emergent layers.

<u>Forest floor</u> The forest floor is the layer of organic humus (decaying leaves, twigs and logs) and the soil.

The physical characteristics of each forest layer create niches and unique habitats within which many species of plants, animals and micro-organisms have adapted. Each layer is important in maintaining the health of the forest and ecosystem.

Ecological Succession

Objectives

1. Understand how forests change ecologically.
2. Recognize disturbances that affect succession.
3. Identify the major stages of succession.
4. Understand how succession affects energy flow.
5. Identify tree species characteristic of Georgia's ecosystems.
6. Understand why we need to identify trees.
7. Know how to use a key to identify trees.

How Forest Ecosystems Change

Forest ecosystems are often disturbed by natural and human activities such as tornadoes, floods, landslides, disease, fires, clearcutting and development. Disturbances do not mean the end of a forest ecosystem. In fact, disturbance is the major force in establishing and maintaining the vegetation component of an ecosystem. Through natural or ecological succession, a forest is regenerated. Succession is the way forests change. It is the orderly and predictable replacement of plant and animal species through time. These changes occur as a result of biological, chemical and physical processes acting alone or in combination. One ecological community of species may take decades or even centuries to completely replace or succeed another ecological community.

Forested land quickly loses it soluble nutrients and minerals after disturbances such as clearcutting, landslides, and soil erosion. Nitrogen is one of the most important nutrients for forest regeneration. Certain pioneer species restore nitrogen to the soil after a disturbance. Some wildflowers, weeds, grasses and certain trees do this. Red alders and black locust are examples of nitrogen fixing tree species. Trees need nitrogen to grow, but most species can neither generate their own nitrogen nor obtain it from the air. They must rely on nitrogen compounds in soils. Red alders and Black locusts, however, have nodules covering the surface of their root systems containing nitrogen-fixing bacteria that convert atmospheric nitrogen into a chemical form usable by plants. When the alder or locust decomposes, this usable nitrogen is added to the soil's nutrient supply and becomes available to successive plant species.

The dynamics of change in a forest are so slow most people do not recognize it. Change in a forest may be modified but not stopped. All forests are moving toward a predetermined forest type (climax) through natural succession. Early succession can be observed in abandoned fields. During the first year, the site will be dominated by grasses and some annual weeds or wildflowers. The second year marks the arrival of perennial weeds or wildflowers and pine seedlings. In the second and third year, hardwood sprouts may begin to appear, but the pines will dominate because they grow faster. Over a period of 10-20 years, many of the grasses and weeds will die out in the shade of the pines. Hardwoods that are shade tolerant will survive as shrubs or small trees beneath the pine canopy. The life span of southern pines is generally less than 200 years. Most individual trees will die long before they reach that age. As pines succumb to natural causes, light reaches the forest floor stimulating the growth of hardwoods. Pines are intolerant of shade; therefore pine seedlings cannot compete with the hardwoods. The result is a hardwood-dominated forest.

As plant composition changes in an ecosystem, there is usually a change in animal species also. Farming, fertilization, irrigation, herbicides, burning and mowing are used to prevent forest regeneration from occurring in croplands, cities and residential yards.

Stages of Succession

Each forest type has its own characteristic species for each stage of succession. There are three main stages of succession: primary, secondary and climax. Each stage has phases that chronicle the progression of species. Biological, chemical and geological cycles are active in this process. Whether a forest is natural or made by humans, or wherever it is located on the globe, these natural cycles are always in motion.

The following pictures illustrate this course for Georgia's piedmont region.

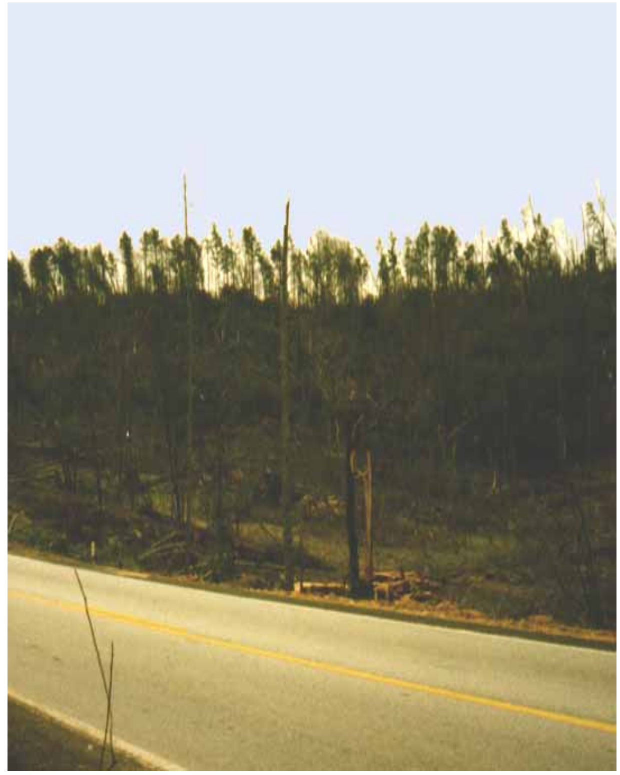
Primary Succession is the first stage of succession in any ecosystem. It begins when the landscape lacks vegetation and fertile soil.

Late Primary/Early Secondary is a phase of succession characterized by pioneer species such as fungi, lichens and mosses. Ferns and grasses follow. Seeds carried by animals or the wind take root. Pines are among the first pioneer tree species to appear in southern ecosystems.

Secondary Succession in Georgia begins as a young pine forest inhabited by small mammals, birds and deer. There are three phases of secondary succession shown on this page.

Mature Pine Forest Pines die out and hardwoods take over as the dominant species. This is still secondary succession. Usually, the first hardwoods to appear in the piedmont forest ecosystems are sweetgum and yellow poplar which are shade tolerant.

Mature Hardwood Forest Years go by and hardwoods take over as the dominant species. A mixture of hardwoods including oaks and hickories are present in the mature hardwood forest on the left. Bear, raccoon, squirrels and birds are some types of wildlife supported in this forest. This is late secondary succession and is the most common phase seen on the Chattahoochee National Forest in north Georgia.



Climax This is the final stage of succession. It is relatively stable under existing climatic and soil conditions. In the southeast, it is characterized by large, old oaks and hickories. This forest supports a variety of plant and animal species in all four layers of the forest. There is very little forest in the United States in this stage of succession. It is usually limited to small pockets of forest in protected areas and parks.

Disturbance Different phases and stages of succession are interrupted by many factors such as natural disasters and human activities. Disturbances such as tornadoes, floods, fire, disease, earthquakes, and timber harvesting take the landscape back to the earlier stage of succession.

How Succession Affects Energy Flow

Green plants are the only living things which directly capture the sun's energy. Through the process of photosynthesis plants make food and give off oxygen as a by-product. This energy is transferred from the sun to plants and to animals through the food chain. The flow of energy on earth is arranged in a pyramid. That is, a broad base of plants supports fewer and fewer animals as the captured solar energy flows upwards through the plants and animals in an ecosystem. It takes about ten times more plants at the base of a pyramid to support the animals at the next level. Those animals will only be able to support l/10th of their number in the level above them.

As energy flows along the food chain, much of it is used up and lost. Plants and animals require much energy to grow. Animal movement uses even more energy. Because of this energy loss, there is less energy available farther up the consumer chain. In most ecosystems there are many plants, fewer plant-eaters, and even fewer animal-eaters.

As energy flows through a forest, some of the energy is used to produce new plant tissue through photosynthesis and some of it is used to maintain the physiological functions. For example, a forest's annual gross productivity might be one million tons of plant tissue while its normal respiration might be 200,000 metric tons, making its net productivity 800,000 metric tons.

As a forest succeeds towards climax, increased amounts of energy are used in biomass maintenance rather than in production. Production and respiration are low in slow-growing, old-growth climax forest. Accumulated biomass is high and of good quality. Only a little energy escapes from the climax forest. Even the temperatures are relatively cool and steady.

Species Characteristic of Georgia's Ecosystems

Mountains This physiographic province is commonly called the Appalachian Highlands or Blue Ridge province. It was formed by faulting and uplifting of resistant, crystalline bedrock. Elevation ranges from 1,000 to over 6,000 feet above sea level in this province which extends into southern Pennsylvania. However, Georgia's highest peak is only 4,784 feet. Mountains area rounded and generally lack prominent angles. Soils are moderately deep and medium textured and generally receive adequate moisture for growth of vegetation throughout the year. The predominant vegetation is oak-pine and oak-hickory broadleaf forest. The following is a list of common species of trees and wildlife found in this north Georgia province.

Trees
Black locust (*Robinia pseudoacacia*)
Chestnut oak (*Quercus prinus)*
Eastern white pine (*Pinus strobes)*
Eastern hemlock (*Tsuga canadensis*)
Northern red oak (*Quercus rubra*)
Post oak (*Quercus stellata)*
Red maple (*Acer rubrum)*
Scarlet oak (*Quercus coccinea*)
Shortleaf pine (*Pinus echinata)*
Sourwood (*Oxydendrum arboretum*)
Virginia pine (*Pinus virginiana*)
White basswood (*Tilia heterophylla*)
White oak (*Quercus alba)*
Yellow buckeye (*Aesculus octandra*)
Yellow poplar (*Liriodendron tulipifera*)

Wildlife (Fauna)
Black bear
Blackburnian warbler
Gray squirrel
Cottontail rabbit
Pileated woodpecker
Screech owl
Whitetail deer
Various species of salamanders

The average precipitation in the mountains is 40 to 60 inches a year but the highest peaks may receive up to 80 inches. Parts of the southern Blue Ridge Mountains bordering the piedmont average over 80 inches of rainfall yearly, which is the highest in the eastern United States. Relatively little precipitation falls as snow. Mean annual temperature is 50 to 62 degrees F and ranges from 38 degrees F in January to 76 degrees F in July. The growing season lasts 150 to 220 days, but varies according to elevation and the local topography.

There is a high density of perennial streams and rivers with moderate rates of flow. However, some streams and rivers in areas of high rainfall have considerable velocity and "white" water. The mountains have several major river basins of critical importance to the state. These are the Tennessee, Coosa, Savannah and Chattahoochee.

Fire, wind, ice and precipitation are the main natural disturbances in the mountains. An introduced pathogen, the Chestnut blight, killed all the American chestnuts from 1920 to 1940 and the species has not come back. One in four trees in the mountains was an American chestnut which provided a reliable nut crop for wildlife. The Gypsy moth which defoliates both hardwoods and softwoods is a more recent threat. The Wooly adelgid threatens the Eastern hemlocks so common on northern slopes and along streams and rivers.

Natural vegetation has been cleared for agriculture and urban development on about 35 percent of the area, mostly in valleys. However agriculture is declining and tourism is a major part of the economy. Retirement and part-time resident communities have also increased rapidly in this region.

Piedmont This province consists of irregular plains. High and low hills make up only 30 percent of the area. Elevations range from 330 to 1,300 feet. Soils are generally deep, with clay or loam subsoil. In many areas soils are severely eroded as a result of past intensive agricultural practices, especially for cotton production.

The average precipitation ranges from 45 to 55 inches in the piedmont. Temperature averages 58 to 64 degrees F. The growing season lasts about 205-235 days. There is moderate density of small and medium size perennial streams and associated rivers with moderate flow and velocity. The Chattahoochee, Coosa, Flint, Ocmulgee, Oconee, Ogeechee and Savannah River basins drain the piedmont.

Agriculture and fire have been the principal historical disturbances in the piedmont. Summer droughts, winter ice storms, tornadoes and insects such as the southern pine beetles, have kept most of this area from reaching its climax vegetation. Most of the area was cleared for cotton production in the 1800's and today urban development is the greatest threat to the forests here.

The predominant vegetation in the piedmont is the pine forest with rounded crowns. The northern piedmont is about an equal mix of hardwoods with a dogwood and sourwood understory.

The following is a list of common tree and wildlife species found here.

Trees	**Wildlife (Fauna)**
American holly (*Illex opaca*)	Northern bobwhite
American sycamore (*Platanus occidentalis*)	Box turtles
Black cherry (*Prunus serotina*)	Northern cardinal
Black locust (*Robinia pseudoacacia*)	Carolina wren
Flowering dogwood (*Cornus florida*)	Cottontail rabbit
Loblolly pine (*Pinus taeda*)	Eastern chipmunk
Mockernut hickory (*Carya tomentosa*)	Fox squirrel
Pignut Hickory (*Carya glabra*)	Gray squirrel
Post oak (*Quercus stellata*)	Gray fox
River birch (*Betula nigra*)	Pine vole
Sassafras (*Sassafras albidum*)	Raccoon
Shortleaf pine (*Pinus echinata*)	Short-tailed shrew
Southern red oak *(Quercus falcate*)	Wild turkey
Sourwood (*Oxydendrum arboretum*)	White-tailed deer
Sweetgum (*Liquidambar styraciflua*)	
Winged elm (*Ulmus alata*)	

Upper Coastal Plain Eighty percent of this province is composed of plains of marine origin. The plains formed when continental sediments were deposited in the submerged, shallow continental shelf. When sea levels diminished, the plains were exposed. Elevations range from 80 to 650 feet. Soils are generally deep, well to poorly drained and have adequate moisture for vegetation during the growing season. Soils are loamy or sandy in the surface layers with loam or clay subsoil. The climax species here are oak-hickory-pine but the dominate forest is evergreen. The following is a list of common trees and wildlife species.

Trees	**Wildlife (Fauna)**
American elm (*Ulmus americana*)	Northern bobwhite
Bitternut hickory (*Carya cordiformis*)	Blue-gray gnatcatcher
Eastern redcedar (*Juniperus virginiana*)	Box turtle
Flowering dogwood (*Cornus florida*)	Northern cardinal
Green ash (*Fraxinus pennsylvanica*)	Common garter snake
Loblolly pine (*Pinus taeda*)	Cotton mouse
Mockernut hickory (*Carya tomentosa*)	Hooded warbler
Pignut hickory (*Carya glabra*)	Mourning dove
Red maple (*Acer rubrum*)	Summer tanager
Shortleaf pine (*Pinus echinata*)	Tufted titmouse
Southern red oak (*Quercus falcate*)	Wild turkey
Sweetgum (*Liquidambar styraaciflua*)	White-tailed deer

In the upper coastal plain rainfall averages 40 to 60 inches annually and the temperature averages 60 to 68 degrees F. The growing season is 200 – 280 days. There is a moderate density of small to medium perennial streams and rivers, most with a moderate volume of water at low velocity. It is drained by many of the same river basins as the piedmont with the addition of the Altamaha. These are the Coosa, Chattahoochee, Flint, Ocmulgee, Oconee, Altamaha, Ogeechee and Savannah.

Like the piedmont, agriculture and fire have been the principal historic disturbances. Summer droughts, winter ice storms and tornadoes occasionally damage the frets in the upper coastal plain. The southern pine beetle insect infestations often cause much damage to forest stands. Natural vegetation has been cleared on about 30 percent of the area for agriculture.

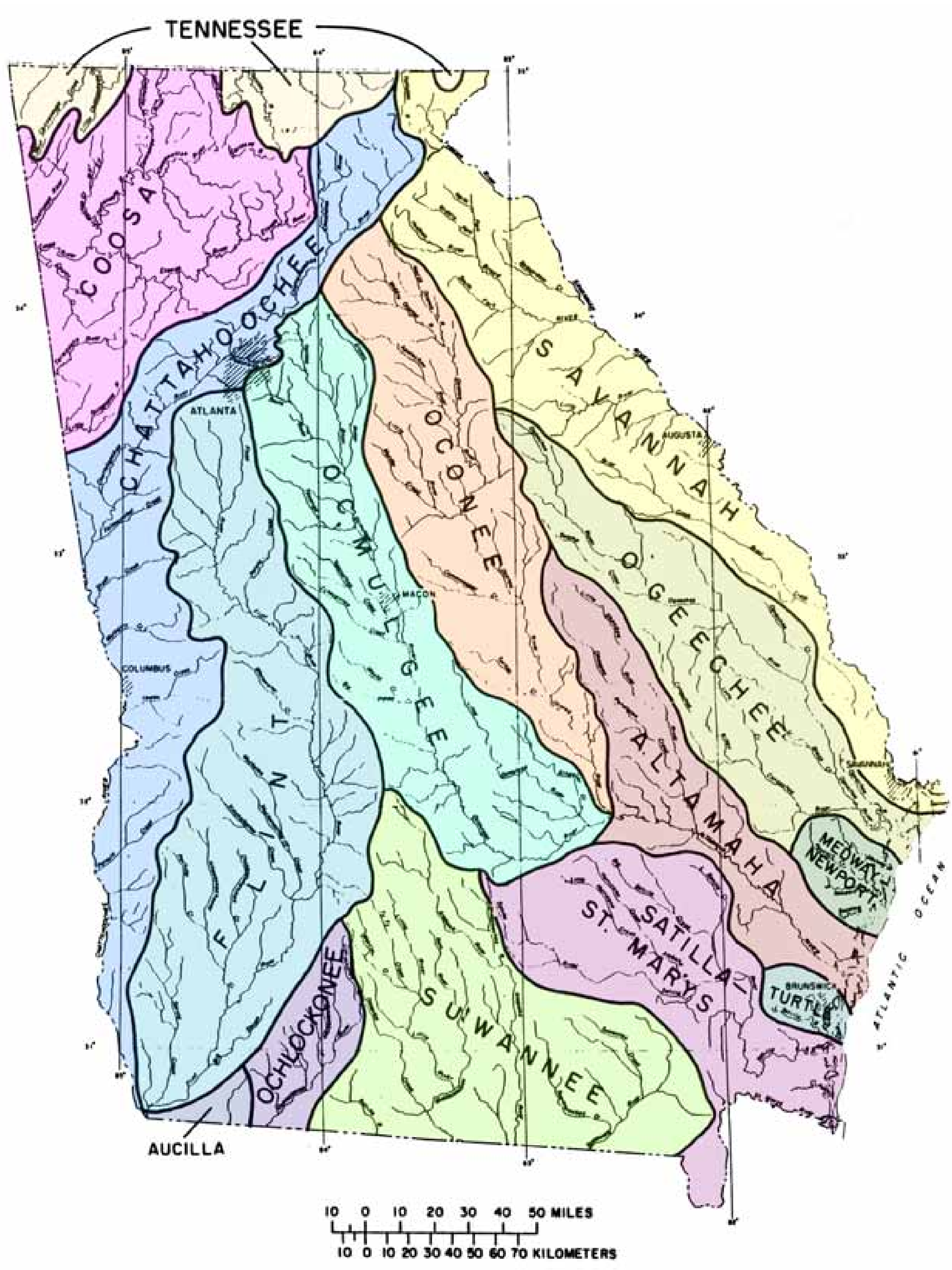
Lower Coastal Plain This flat, alluvial plain was formed by deposition of continental sediments onto the submerged, shallow continental shelf, which was later exposed when the sea level subsided. Elevation ranges from 0 to 80 feet above sea level. Soils are deep, finely textured and have adequate to excessive moisture for vegetation during the growing season. The climax forest is oak-hickory-pine, but the predominant species are evergreens. See the list below for trees and wildlife you might expect to find in this ecosystem.

Trees	**Wildlife (Fauna)**
Baldcypress (*Taxodium distichum*)	Box turtle
Flowering dogwood (*Cornus florida*)	Cormorant
Laurel oak (*Quercus laurifolia*)	Cottontail rabbit
Live oak (*Quercus virginiana*)	Eastern indigo snake
Loblolly pine (*Pinus taeda*)	Egret
Longleaf pine (*Pinus palustris*)	Gopher tortoise
Red mulberry (*Morus rubra)*	Heron
Slash pine (*Pinus elliottii*)	Ibises
Southern magnolia (*Magnolia grandiflora*)	Kingfisher
Sweetbay magnolia (*Magnolia virginiana*)	Ruby-throated hummingbird
Water hickory (*Carya aquatica*)	Summer tanager
Water oak (*Quercus nigra*)	Striped skunk
Yellow poplar (*Liriodendron tulipifera*)	Swamp rabbit

Annual precipitation averages 46 inches. Temperature averages 55-57 degrees F and the growing season last 185-220 days in the lower coastal plain. There is a moderate density of small to medium size perennial streams and a low density of rivers. Most have a moderate volume of water moving at a very low velocity. The major river basins include the Savannah, Ogeechee, Medway-Newport, Altamaha, Satilla-St. Marys, Turtle, Suwanee, Ochlockonee and the Aucilla. Fire and hurricanes are the main disturbances, but southern pine beetle infestations destroy thousands of acres of pines in this region.

It is important to note that the species list included under each region is only a fraction of the tree and wildlife species supported in each physiographic province. The lists given are the most common species in that area. Notice many of the species are found throughout the state. These species have adapted very well to the differences in rainfall, soil types, temperatures and elevation found from north to south Georgia.

Major River Basins of Georgia (Approximate locations)



Tree Identification

Why should we learn to identify different trees? Different species of trees grow close to water, on high ridges, in different soil types, etc. It is very important for foresters and other natural resource professionals to know the species makeup of the forest. On public lands, botanist inventory plant communities in the forest before any timber management action that could adversely affect the ecological relationships are undertaken. Threatened or endangered species may exist in an area to be harvested so measures must be implemented to protect these species. This usually means creating a buffer zone around such species where no harvesting will take place.

Cultural resource surveys are also conducted to determine prehistoric and historic uses of the land before ground disturbing management activities begin. Significant cultural findings are protected as these are non-renewable resources. Often trees help date an archaeological site. The type trees found at the site may give clues to past land use.

Knowing species composition is important for prescribed burning and smoke management. Different plant materials burn at different temperatures and some plants such as poison ivy release oils in the smoke when burned. If this smoke is inhaled, it can cause serious and even fatal lung infections. Different species of trees have different economic value both for lumber and other uses. This is always changing. In the early 1980’s the Pacific yew had little economic value. In fact, it was considered a “weed” species in the northwestern forests. Then the cancer-fighting drug, taxol was discovered which is only derived from the bark of the Pacific yew. Needless to say, this tree is now quite valuable.

All trees can be classified into two specific families—gymnosperms and angiosperms. Gymnosperms are generally the conifers or cone bearing trees and for the most part, are evergreens. Gymnosperms bear naked seeds, often on a scale. Angiosperm seeds, in contrast, are enclosed by the ovary. Angiosperms include hardwood trees and are mostly deciduous, meaning they shed their leaves in the fall. Trees are identified by their seeds, shape of their leaves or needles, the arrangement of the leaves, bark and even shape of the crown. Additional identifiers are their flower, fruits, habitat, taste or smell. It takes observation, study and practice to correctly identify trees. One tree may have many common names that vary by location. For technical accuracy, to eliminate language barriers and facilitate effective communication, the scientific naming system was developed. The development of a universally accepted system using scientific names has resulted in more effective communication among scientists and has furthered research.

Using a tree key

A tree identification key is a tool such as a book, a disk, a web site, that is used to identify trees. Parts of a tree, usually the leaves, are the most distinguishing feature of a certain species. However, if it is a deciduous tree and it is winter, the leaves are not much help. Neither are they much help if it is a tall tree and you can’t examine the individual leaves. A tree key will list parts of the tree that will help distinguish it from other trees even in the same genus. You observe tree characteristics and look them up in the key. The more characteristics you can use and apply, the greater accuracy your identification will be. Here are some examples of tree characteristics to note.

Twigs Are the twigs slender or chubby? Smooth or hairy? Any spots, ridges, or special colors? The most recent growth of Boxelder twigs has a purplish color.

Buds Pointy or blunt? Shiny or dull? Hairy or smooth? Big or small? What colors? Sugar maples have very pointy buds. Oaks have a cluster of end buds.

Bark Bark can be difficult to learn because most trees have bark that changes appearance with age. Identifying characteristics involve thickness, roughness, color and even smell. Some trees like birch have papery bark, white pine has scaly bark.

Flowers We don't normally think of trees with flowers but all trees have them. Flowers are good identifying parts. Red maple, dogwoods and redbuds are among the first trees to bloom in the spring.

Fruits All trees have fruits too. Cones, nuts, acorns, seeds and helicopters are just some of the many kinds of fruits that trees produce. A fruit is any kind of organ that holds seeds, not just edible fruits like apples or pecans.

Branching pattern The way a tree branches can sometimes be helpful. Opposite branching occurs in maples and ashes. Some shrubs also have opposite branching so tree sapling identification may be harder. Most trees have alternate branching. The angle at which branches come off the trunk or the density of branches in the crown can be good clues in tree ID.

Tree form The overall shape of a tree is the form. Some trees have very distinctive form such as the American elm is shaped like a large flower vase.

Leaves Leaves include needles and scales of conifers. How are they arranged: opposite, alternate or whorled? Are they simple or compound? Are they shaped like the palm of your hand? Are the leaf edges smooth, rough, lobed, pointed, wavy, or rolled under? How are the leaves shaped: oval, elliptical, linear, or oblong? How big are the leaves, how are they textured and is there color variation?

Growing site Some trees, like cedar, black spruce and tamarack are usually found on wet sites. Yellow birch and hemlock grow in cooler, moister places like ravines and the north side of hills. What trees are growing near them?

Tree identification skills take practice. It requires observation and classification abilities but will help you understand what is happening in that forest and what else might be living with those trees.
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Forest Management

Objectives

1. Describe how and why forestry began in the United States.
2. Identify forest managing agencies.
3. Understand how a tree grows and how leaves change colors.
4. Know how to determine the age of a tree.
5. Know how trees are measured for market.
6. Identify forest management methods.
7. Understand best management practices.

History of Forestry

The study of forestry first began in Germany in 1770 and spread to France in 1824. The United States expressed little interest in forestry schools or in applying scientific management to forest lands until the late 1800's. The pioneers found America blessed with thousands of acres of mature and climax forests so vast the resource was thought to be endless, so little thought was given to replanting as trees were cut down. It was not until Dr. Carl A. Schenck, a German forester, came to America to manage the Biltmore Estate forests in North Carolina that people realized what was happening by over harvesting. Schenck started America's first forestry school near Asheville. Here he taught woodsmen conservation of forest resources. Another conservation leader was Gifford Pinchot who is often called the father of American Forestry. He convinced Americans that our forests are renewable resources and proved that good forestry management could produce a perpetual timber harvest demonstrated on the Biltmore Estate in Asheville, North Carolina.

The first government forestry organization, the Division of Forestry was established in 1880 under the Department of Interior. Bernhard Fernow was its head. This fledgling agency advocated government action to protect natural resources in a rational manner. In 1901, the Bureau of Forestry was established and Gifford Pinchot was named its chief in charge of the recently created Forest Reserves. These reserves were lands set aside by the Creative Act of 1891 from public domain as permanent reservations for eventual use as forests. In 1905, the Bureau of Forestry was transferred to the Department of Agriculture and renamed the Forest Service.

The USDA Forest Service

The Forest Service was placed under the Department of Agriculture because it grows trees. Most of the land that is National Forests today in the east was purchased from willing sellers because it was land no one wanted. It had been cut-over, mined, over-grazed, over-farmed or otherwise abused. It was the task of the Forest Service to restore the land by planting trees to protect the watershed and properly manage the land so that a continuous supply of timber could be assured.

Since the agency was established, its role has greatly expanded. There are 155 national forests, 20 national grasslands and 222 research and experimental forests. The agency manages wildlife and fisheries habitat and protects forests from fire. In recent years, protecting air and water quality are receiving increased emphasis. The Forest Service also cooperates with state forestry agencies such as the Georgia Forestry Commission, to encourage good management of privately owned forests including urban forests. The research branch of the Forest Service conducts studies, experiments and tests to find better ways of managing trees, developing and/or improving forest products, insect and disease control, fish management and even ways to recycle forest products. Professionals from many disciplines are required to perform these tasks and to carry out the agency's mission of caring for the land and serving people.

The Chattahoochee-Oconee National Forests is made up of 750,000 acres in North Georgia stretching from the North and South Carolina borders westward to Alabama and northward to Tennessee. The Oconee contains over 115,000 acres and is located in the piedmont. The forests are required by law to be managed for water, timber fish and wildlife, range and recreation which includes wilderness.

The Georgia Forestry Commission

The Georgia Forestry Commission (GFC) is the state agency responsible for providing leadership, service, and education in the protection and conservation of Georgia's forest resources. Legislation in 1925 created the Georgia Forestry Department and subsequent legislation in 1949, the Georgia Forestry Commission. The vision of GFC is healthy, sustainable forests providing clean air, clean water, and abundant products for future generations.

The Commission's central office is located in Macon, Georgia and the Director of the GFC is known as the State Forester. The Commission has district and county offices providing services to every county throughout the state. Services provided include: wildfire prevention education and services, issuing burn permits, wildland firefighting, emergency response and incident command system expertise, education, assessment, and mitigation assistance to homeowners and communities concerning wildland-urban interface issues, equipment and training to rural fire departments, professional forest management advice and services to landowners, professional forest management advice and services to communities, administration of cost-share and conservation programs, assistance and information for the marketing and utilization of forest products and nature services, quality tree seedlings and educational information and opportunities about forests and forestry.

Private Industry

Forests are the most predominant feature of Georgia's landscape. Of the 37 million acres of land in Georgia, approximately 24 million acres are classified as timberland. Georgia is the largest timber producing state in the southeast. Private, non-industrial landowners own 68 percent of all forest acreage in Georgia. The commercial forest industry (timber companies such as Georgia Pacific, International Paper, Weyerhaeuser, etc.) owns 25 percent and the government (federal, state and local) owns 7 percent of Georgia's timberland. This multi-billion dollar industry ships paper and wood products to markets worldwide.

Private Organizations

Much of the forest community belongs to the Georgia Forestry Association (GFA), one of the oldest professional conservation organizations in the United States, founded in 1907. The GFA works with landowners protecting property rights and adopting sound land management practices to ensure that our forests continue to provide our ecological as well as product needs now and in the future. The GFA supports and practices objectives outlined in the Sustainable Forestry Initiative (SFI), one of the most far-reaching changes in forest management and conservation in the history of the United States forest and paper community. These principles include guidelines to protect water quality, wildlife, soil and plant communities when timber is harvested. Over 92 percent of Georgia's commercial forest acreage is in compliance with the guidelines but a goal of 100 percent is the target.

How does a tree grow?

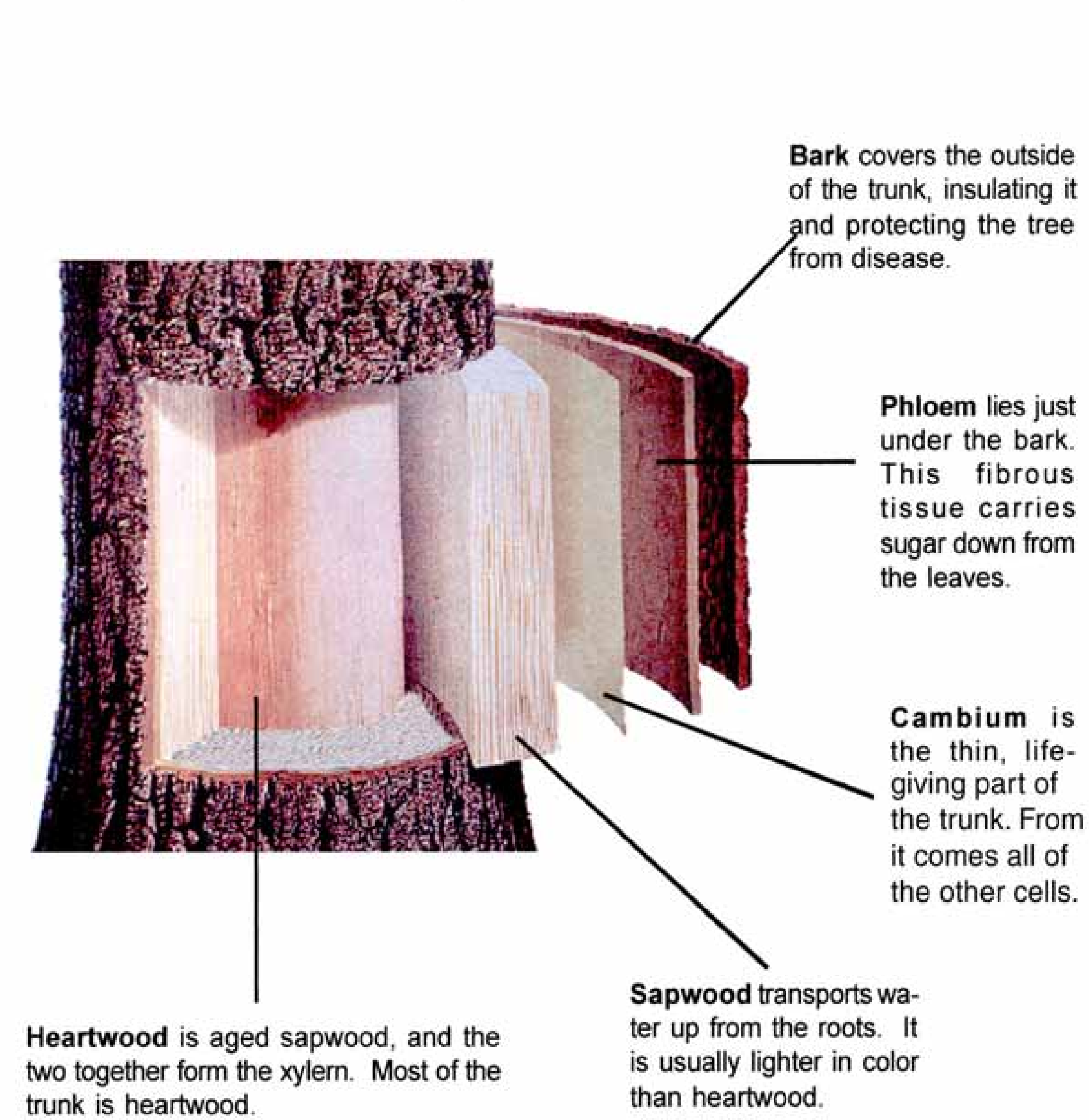
Forest management not only requires skills in forest management methods but it begins with a basic knowledge of the physiology of trees and factors that affect them. Trees produce sugars which are converted to amino acids, enzymes and other compounds including wood. This fundamental manufacturing process is called photosynthesis ("photo" meaning "light" and "synthesis" meaning "to put together"). Sunlight provides the energy for the leaf "factories". In the leaves, water from the roots combines with carbon dioxide from the air to form simple sugars like glucose. This process is carried on inside each leaf by millions of green-colored, microscopic chloroplasts. Taken together, these tiny pigments are called chlorophyll. They give leaves their worldwide green color. Glucose is used by the tree to grow. Oxygen is produced as a by-product of this process and is released into the atmosphere.

Although we cannot see it happening, trees are continuously losing water through their leaves. The undersides of leaves are covered with millions of microscopic openings, or pores, called stomata. These tiny pores open to allow carbon dioxide to move in and oxygen to move out of the leaves. Water vapor also passes out through the stomata in a process called transpiration. A small tree can transpire several hundred gallons of water a day. This is a very important function of the water cycle. The water lost from leaves is replaced by water absorbed by roots and moves up into the tree through the sapwood (xylem).

Trees have three main growing parts, the root tips, the stem tips, and the cambium layer which is found between the bark and the wood throughout the tree. The growing points of the stems develop into branches, leaves and flowers; the flowers become fruits or nuts, maturing into seeds. The cambium produces all of the other cells. Trees increase height and spread branches by adding a new growth of twigs from young cells in the buds at the ends of the twigs. The sugar made in the leaves is carried by a network of tiny sieve tubes in the inner bark (phloem) to all living cells in the tree. Every living cell from root tips to crown tips works on the sugar with the aid of special enzymes to make it into new products. Enzymes start or speed up certain chemical reactions. Each enzyme does a special job, working with split-second timing in harmony with the others. In general, the enzymes break down sugar and recombine it with the nitrogen and minerals which are dissolved in the water carried up by the xylem from the root tips.

The trunk of the tree has five main layers, each with a special function. These are illustrated by the diagram.

Layers of a Tree



The root system of trees can be very extensive. Some roots may extend down into the soil 12 to 30 feet or more. Lateral roots may extend from the trunk for long distances also, often 35 or more feet in each direction. Most feeding roots are in the top 2 or 3 feet of soil. The type tree, its age, type of soil, moisture available, competing vegetation and other factors determine the extent of the root system.

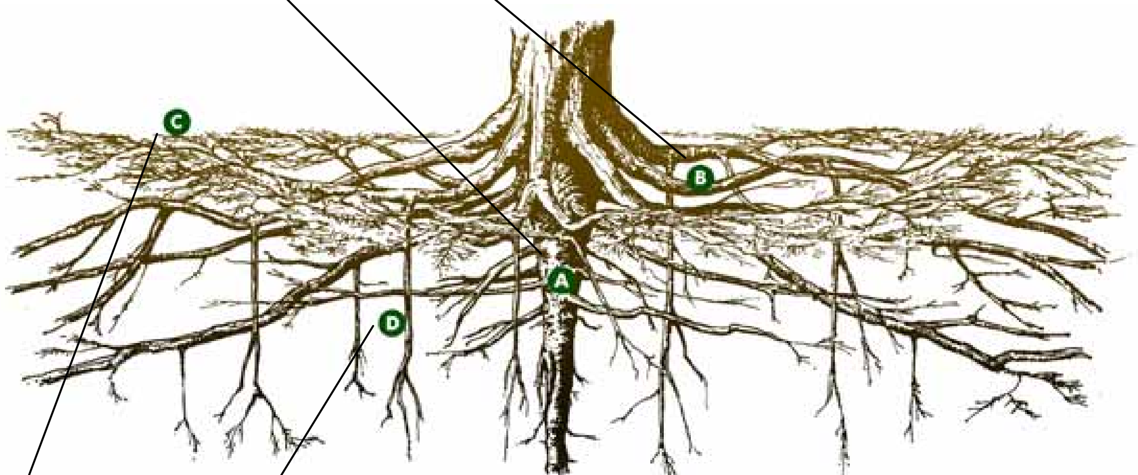
The life spans of the fine tree roots differ according to the tree species. The fine roots of pine trees last four to six years while sweetgum roots have shorter life spans of one to three years. This turnover rate is important when calculating the amount of excess carbon a tree is able to sequester. Trees with fast root production, can store more carbon in the soil and roots than trees such as pines with slower root replacement.

The root system of a tree has four main types of roots that help anchor it and perform special functions.

Roots of a Tree

A – Taproot provides main support for the tree (not all trees have taproots).

B - Lateral roots help support and anchor the trunk and may extend far beyond the crown spread.



C – Feeder roots capture nutrients and hold soil. They form fibrous masses close to the ground surface.

D – Sinkers grow downward from lateral roots deep into the soil.

How do leaves change colors?

Scientists do not fully understand all of the complicated interactions involving pigments, sunlight, moisture, chemicals, hormones, temperatures, length of daylight, site, genetic traits, etc. that make a perfect autumn color display. The process begins in the fall when the next year's leaf buds are set; continues into spring when pigments develop and through the summer growing season into the fall when the colors are displayed. If weather conditions are not optimal during each of these periods, the amount of leaves on the trees will be affected as well as the color development.

A leaf is green because it has a group of pigments known as chlorophylls which are essential to plant growth. When chlorophylls are abundant, the green masks the other pigments present in the leaf. Chlorophylls capture the sun's energy and use it along with carbon dioxide and water to manufacture glucose. In this process, the chlorophylls are continually being broken down and replenished during the growing season. As autumn approaches, the chlorophylls are replaced at a slower rate than they are used so the other pigments begin showing through. One group of pigments that give the yellow, brown, and orange colorations are carotenoids, Another group of pigments that give the reds, purples and their blended combinations are called anthocyanins. Carotenoids are present all along, but the anthocyanins usually develop in late summer. Their formation depends on the breakdown of sugars in the presence of bright light as phosphate in the leaf is reduced.

In the fall, phosphate and other chemical nutrients move out of the leaf into the stem of the plant. The sugar breakdown process changes when this happens, leading to production of anthocyanin pigments. The brightest colorations usually develop if the sunlight is strong and the nights chilly but not freezing.

Leaf watching has become a popular attraction to the country's forests boosting tourism economies. This social and economic factor plays a significant role in forest management decisions.

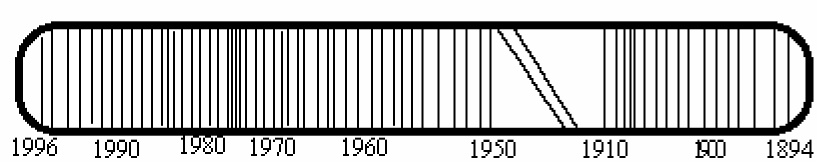
How to determine the age of a tree

The best way of determining the age of a tree is to know when it was planted. This is often not possible, however, and other methods are used. Tree rings are the annual growth rings produced by trees. Trees in temperate zones grow one ring per year. As a tree grows in the spring, the cambium layer produces large, thin-walled xylem cells that form a light-colored ring in the sapwood. Growth slows down in late summer and fall, and the cells are smaller and thicker-walled, appearing as a darker ring. Each light and dark ring together is an annual ring and represents one year of the tree's growth. You can count the annual rings to determine the tree's age. Ring width is very small in old trees. Early or late frosts sometimes promote formation of false rings which do not completely encircle the tree and are not typical of the growth pattern. Annual rings at the base of the tree will give the true age of the tree. Annual rings at the top of the tree give only the age of the top of the tree. Annual rings of a branch give the age of the tree branch.

Distinct rings do not occur in all species. Tropical forest species do not clearly exhibit these rings and even some temperate forest species such as Red maple and Blackgum do not show clearly visible rings. Dating a tree without rings can also be done by measuring its growth rate or by using chemical analysis, such as radiocarbon dating. Growth rate over a given time can be extrapolated to the entire lifespan of the tree however, this can be very inaccurate.

Foresters use a threaded, hollow increment borer to extract a pencil-sized core of wood from a standing tree to determine the age and condition and to analyze the growth rate of a tree. In boring any tree there is a level of risk associated with the long term effects of the core hole. The degree of risk depends upon the species and the coring process. In all cases, a very sharp borer should be used and core should slope slightly upward so that water and sap can drain out rather than into the tree. Do not plug holes with dowels or other objects as they increase the rate of stem cracking and cambial dieback. Also do not use wound dressings or paint and do not tag trees with nails or staples. In trees with compartmentalized decay as in heartrot, coring can spread the infection to the sapwood. Softwood (coniferous) trees with their crowns in the canopy and in less crowded conditions are best choices for coring.

The tree core, once extracted from the tree, may be safely carried back to the lab in a plastic straw. At the lab, the core should be removed from the straw and allowed to dry overnight. Core is then glued into a narrow board so that the wood grain (annual rings) is on top. After the glue has dried, the core is sanded to remove scratches, resulting in a smooth surface with distinct boundaries between tree rings. To date the core, a dot-marking system is most commonly used. One pencil dot is placed in the ring produced in each decade, two dots on half-century years and three dots on century years. Using this method, it is easy to quickly find rings produced in certain years.



Tree rings tell us about the tree's history. Wide rings show years of rapid growth, perhaps due to plentiful rain or lots of growing space. Narrow rings represent slow growth caused by drought or stress to the tree. A scar across the rings shows that fire or disease struck the tree. Growth of each 5 or 10 consecutive rings may be measured to the nearest 0.5 mm and then plotted (growth on the Y axis and years on the X axis). Patterns may then be compared to known weather conditions or other environmental phenomena. Growth in certain years may be compared to known droughts or forest fires. The study of tree rings is dendrochronology (from the Greek, dendros meaning tree and chronos meaning time). Do not confuse dendrochronology with dendrology. Dendrology is the study of woody plants including shrubs as well as trees.

How long do trees live?

Most pines live 80-100 years and hardwoods live 150-250 years in Georgia's ecosystems. However, just as some people live longer than others, so do trees. Every species has its own genetically determined maximum life span. The *maximum* age of some of Georgia's species under optimal conditions that may or may not occur in Georgia follow:

White oak, Sycamore, White pine	450-600 years
Beech	300-400 years
Eastern redcedar, Loblolly pine, Tulip Poplar, Sweetgum	240-350 years
Shagbark hickory	250-300 years
Northern red oak, Red maple	150-300 years
Black walnut, Black oak	200-250 years
Black cherry, Shortleaf pine	150-200 years

The world's oldest living things are trees. The Bristlecone pine is a species which lives thousands of years. The oldest of these is over 4,700 years old and is named the "Methuselah". It grows atop the White Mountains in the Inyo National Forest in California. Most pines, in the south, do not live much past 80 before disease or insect infestation kills them while some oaks may live 200 years before disease or insects strike. Scientists and novices alike have been fascinated over the Bristlecone's ability to adapt to change and live under harsh conditions for thousands of years. These trees are a tourist attraction as well as the subject of nature study and research.

Pines are usually harvested at 30-40 year rotations for pulpwood or sawtimber where they are being managed for this purpose. Hardwoods are harvested at 80-100 year rotations for lumber. This allows the greatest return economically before the trees start their decline. The time of harvest for timber is determined by the product desired. For example, trees managed for pulpwood can be harvested at an early age while high quality sawtimber is harvested after the tree matures. Once the product desired is known, the volume or amount of lumber in a specified area or "compartment" determines the time of harvest. Other factors are important too in determining time of harvest such as market, time of year, regeneration method to be used and whether the cut is a salvage operation.

How do you measure standing trees?

One of the standards for determining how much lumber a tree contains is the board foot. It is the smallest measure of volume for timber, equivalent to a piece of wood 12 inches square (30 cm) and 1 inch (2.5 cm) thick or 144 cubic inches (12 x 12 = 144). This fact makes it easy to calculate the number of board feet in lumber of any size. For example a 2”x 4”that is 8 feet long has 5.3 board feet.

$$\frac{8 \text{ ft. } (12'') \times (2)\ (4)}{144} = 5.3 \text{ board feet.} \qquad \text{Or } \frac{(8)(2)(4)}{12} = 5.3 \text{ board feet}$$

The volume of wood in standing trees may be obtained by taking three measurements and applying them to tree scale volume tables or a mathematical equation. Measurements needed are diameter, merchantable height and amount of taper in the trunk of the trees. These measurements are recorded in a data recorder or tally sheet for the compartment of trees before they are marketed.

Tree diameter

Tree diameter is measured at 4.5 feet above the ground on the high side of the tree, a point referred to as “diameter at breast height” or DBH. The most common method to determine DBH is to use a DBH tape. Another way without this tool is to measure the circumference at 4.5 feet above the ground with a measuring tape. Apply the formula, D= C -:- 3.14 (pi).

Merchantable height

Merchantable height is the usable length of a tree. It is measured from “stump height” (6 inches above the ground) to the “cut off” point where the tree reaches its recommended small-end diameter. The taper beyond the cut off point is usually too small to be used for the purpose the tree is being harvested. The cut off point will vary depending on the tree species, the local market, and the end uses of the logs. For example, the cut-off point for pulpwood would be 2-3 inches, for chip’n’saw it is 4-6 inches and 8-10 inches for sawtimber.

Trees are considered sawtimber if they are of good form, free of major defects and are large enough for good lumber. They are measured in board feet or metric tons. The standard log length for sawtimber is 16 feet and a half log is 8 feet. The cut off point is a minimum of 8 inches or where there is a major fork in the tree. A tree with a merchantable height of 40 feet would be recorded as a 2.5 log tree.

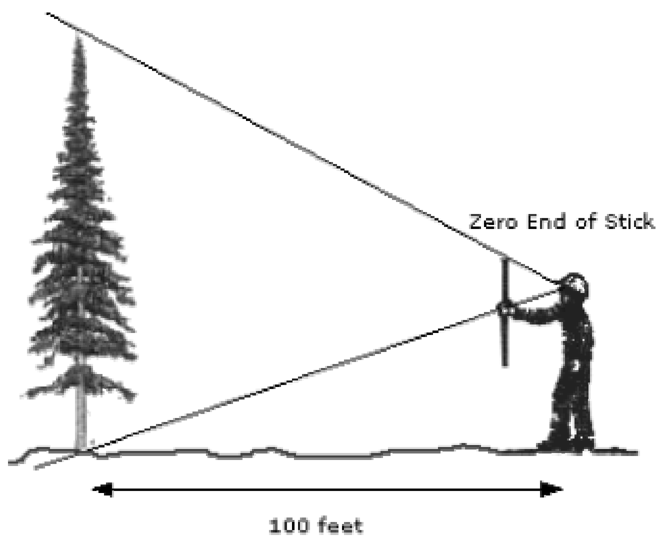
Pulpwood are trees that will be used to make paper and thousands of other products made possible by pulp. Pulpwood is measured in board feet, in metric tons and sometimes in cords. For pulpwood, the standard log length is measured to the nearest 10-foot class. A tree that is measured at 44 feet for pulpwood would be in the 40-ft height class and a tree measured at 58 feet would be in the 60-foot class. Most pulpwood is hauled tree length to the mill.

Chip'n'saw trees are used for smaller lumber and are chipped for planeboard and paper. They are usually measured in cords. Cords are often converted to tons. A cord is a standard stack of wood measuring 4'X 4' X 8', or 128 cubic feet.

Other merchantable timber such as poles and veneer logs are exceptional form class and are measured as high quality sawtimber. Fence posts and pilings are measured like pulpwood.

Using tree scale tools

A tree scale tool like the Biltmore Stick or Clinometer is used to determine merchantable height of standing trees. The diagram below illustrates a Biltmore Stick being used.



To measure a standing tree with a Biltmore Stick, pace or measure a distance of 100 feet from the tree. Hold the stick vertically at 25 inches from your eyes with the hypsometer side facing you and parallel to the tree. Align top end of stick (zero end) with the top of the tree. Without moving your head, sight down the stick to ground level at base of tree. Read height from scale where your line of sight and the base of the tree intersect.

A clinometer is an ocular device used to determine tree height when the distance from the tree is known. It can also be used to determine slope in either percent or degrees. When the user sights through the eyepiece, a rotating wheel with a scale printed on it can be seen and a red line indicating the horizontal plane. The scale had degrees on the left and percent on the right. Be careful to ensure the correct scale is read.

For determining slope, look through the eyepiece holding the clinometer vertically and align the red horizontal band with an object of equal height to your eye. Another person would be ideal. Have that person move away in the direction of the slope so that a sighting can be made to a point on their body. Then read the scale in degrees or percent.

To determine tree height, move away from the tree in a direction where the slope is less than 120 percent to a baseline distance of 66, 80 or 100 feet. Check your clinometer for the baseline distance calibration. Keep both eyes open when taking readings and do not obstruct vision with supporting hand. Sight to the bottom of the tree and read the percent scale, then sight the top of the tree without moving your head and read the percent scale. Add the two distances. Multiply this total percentage times your baseline distance (66, 80 or 100 usually) to get your tree height.

If the tree is on sloping ground and the base of the tree is ABOVE eye level, sight the top of the tree, then the base. Subtract the two readings, then multiple by the baseline distance to get tree height. If the base of the tree is BELOW eye level, sight the top, the the base and add the two readings, then multiply by the baseline.

Using forestry tools accurately requires practice. Seek help to thoroughly understand the proper techniques and methods.

<u>Calculating Board Feet</u>

Once you determine the DBH, and merchantable height of the trees in a compartment, you can determine the number of useable logs and the board feet in each. The Scribner Log Rule (Appendix B) is usually used to determine board feet of pine trees after measurements have been taken. The Doyle Log Rule is usually used to determine the board feet of hardwoods because of the way it handles taper. Taper is usually greater in hardwoods than in pines. Tree measurements and board feet are often recorded on a tally sheet similar to the example below.

Number of Usable 16' logs														
Tree	**Dbh**	**Height**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**Board Feet**
1	20	60'						*						398
2	15	55'					*							178
3	18	50'					*							280
													Total Board Feet	856

Data recorders are types of computers that have replaced tally cards in most large forestry operations. With these, measurements can be entered as they are taken in the timber stand. Total volumes are given instantaneously by the touch of a key. The total number of trees in each category (such as all trees with a 20" dbh and 60' tall) are counted and then multiplied by the volume of wood in each tree. That number, in turn can be "blown up" according to the number of acres being sampled to determine the total volume in a stand.

Weight Scaling

The trend toward buying timber by weight is strong in the South. Sawlogs, pulpwood, poles, fence posts and other products traditionally bought by board feet, cords or by other standards, are being sold by weight in many areas. The advantages of weight scaling are it is more accurate, quicker, and saves time for the buyer and seller. It encourages prompt delivery of green wood to the mill desirable from a processing standpoint. A greater volume of wood can be handled in less time with less people and inventories are more easily maintained using weight scaling.

The disadvantages of weight scaling involves fairness to buyer and seller. Questions such as what are the exact weight equivalents for a thousand board feet of sawlogs or a cord of pulpwood? This is difficult to answer because of the variables associated with wood such as moisture content and wood density that varies so with each species, the season of the year, the growth rate and position of the tree in the stand.

Several pulp companies have developed average weights per cord, taking into account the above factors and are using these weights. The weight equivalents vary by species, mills and localities or points of origin. Weights per cord currently being used by pulp companies in the southeast average 5,232 pound for pine and 5,758 pounds for hardwood.

The quality and size of sawlogs cannot be determined by weight. Knotty, crooked logs may weigh the same as clear, straight logs. A truckload of small logs may weigh the same as a truckload of large logs but yield less lumber per unit of weight. Several studies have been made in the south to determine weight-volume relationships of southern pine logs. It was concluded that data developed by a specific mill for its own use is the most accurate as they factor in their utilization practices affecting yield. The data obtained by one mill would not necessarily apply to logs procured by another mill. Georgia sawmills use average weights from 12,000-17,500 pounds per thousand board feet of sawlogs.

Forest Management Methods

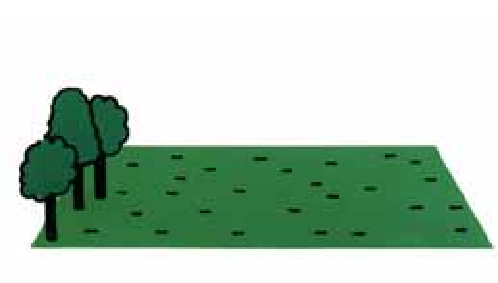
Silviculture is the art and science of managing and tending a forest. When a series of cultural practices are planned into the long-term management of a forest stand, the total program is a silvicultural system. This system has implications throughout the life of the stand. The system usually takes its name from the final harvest method such as clearcut, seed tree or shelterwood. Planning a system depends on the objectives, the tree species, the current condition of the forest, tax issues and the land itself. For example, mountain land would not be suitable for growing baldcypress and lower coastal plain swamps would not support white pine. One objective might be to grow only pine pulpwood, another to grow high quality sawlogs. Management objectives should also include non-timber purposes such as wildlife habitat, watershed protection, and scenery.

Determining the length of time between establishing the stand and the final harvest is called the rotation or length. Pulpwood normally has a rotation length of 20-30 years, small sawtimber 30-50 years, and large sawtimber 50-80 years. Prescribed burning, a system of burning the underbrush and forest litter buildup, as well as thinning are appropriate silvicultural tools in southern pine stands but are not usually recommended for hardwood stands.

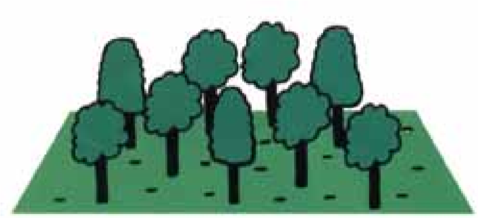
There are basically two silviculture management regimes, *even-age* and *uneven age management*. Both these systems mimic disturbances that occur in natural succession. For instance, sometimes wind, fire, ice storms or disease and insect infestation can kill a forest in a short time. When the forest regrows, the new trees are all about the same age, even though size may vary with growth rates. This type of forest is called "even-aged". Other times, a forest may grow for many years with only small groups or individual trees dying. This provides open spaces that soon will be filled by young trees. These forests are called "uneven-aged".

Over time, each type of forest will take on a different appearance. Certain trees, such as Black cherry, oak, hickory and pine, grow best if they are managed as even-aged forests because they have high needs for direct sunlight. Other trees, such as hemlock, maple, dogwood, and beech, can thrive in the shaded environment of an uneven-aged forest. As with the different stages of natural succession, each type of forest supports different wildlife habitats. To imitate nature's methods of regenerating forests, different cutting practices are used for each.

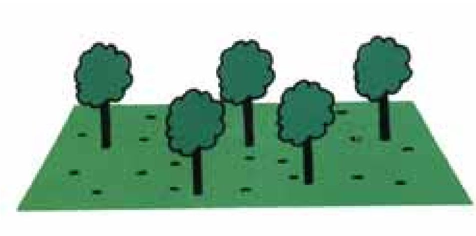
Cutting methods for even-aged management:



Clearcutting removes all merchantable trees from a specific area at one time, except trees reserved for special purposes such as wildlife habitat. This maximizes available sunlight for new tree growth and benefits many species of wildlife that browse on young vegetation and soft mast. Reforestation can be accomplished by allowing natural regeneration to occur, by sowing seeds across the land or planting seedlings. Planting allows the manager to control the species and spacing between trees. Planting also gives the option of planting genetically improved seedlings which grow faster and are more resistant to disease. Unlike ornamental trees or shrubs, forest tree seedlings are most frequently planted in winter and early spring. This allows the seedlings to become acclimated to the new environment during the dormant season, thus reducing the shock of transplanting and competition for nutrients.



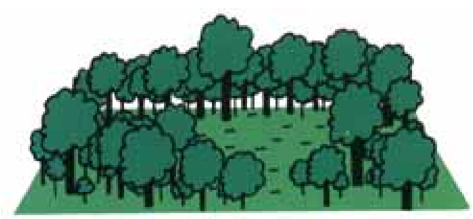
Shelterwood cutting removes forty to 40-60 percent of the trees allowing new trees to become established in partial sunlight under the shelter of the remaining older trees. Remaining older trees are removed after the new trees are established.



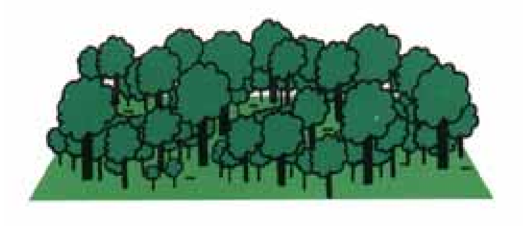
Seed tree cutting removes most of the trees in one cut, leaving 4-12, well-spaced seed producers per acre. This method is used mostly in pine stands. During the rotation the stand will be protected from wildfire, insects and disease so the seed source will not be lost. Prescribed burning will probably be conducted every 3-5 years and about five years before the end of the rotation, burning will be done more frequently to expose patches of mineral soil on the forest floor for seeds to germinate and grow. Seed trees will be harvested after a new forest has been adequately established.

Cutting methods for uneven-aged management

Group selection cuts small groups of trees in one-quarter to two acre plots. This creates larger openings for regeneration of trees which require partial sunlight.



Individual tree selection cuts trees of various sizes, dispersed throughout the forest individually selected for cutting. This creates small openings for establishement of shade tolerant species.



Coppice System

The coppice system is a forest originating mainly from sprouts or root suckers rather than seed. This is viable for hardwoods and can be used for both even and uneven age management of forest stands. When a hardwood tree is cut, dormant buds beneath the bark of the stump are stimulated. New sprouts grow from these buds, frequently resulting in a clump of new trees all coming from one stump. These new sprouts grow rapidly because they are still served by the large root system of the parent tree. There are many variations of the coppice system. The most basic method is to harvest a hardwood stand and allow nature to take its course. Another method is to harvest, wait for sprouts to appear, then remove all but one healthy sprout from each stump.

Prescribed Burning

Woods burning under controlled conditions and for a particular purpose is called prescribed burning". It differs from a wildfire in t hat it is intentionally set and controlled to achieve a specific goal. The reasons for brning include the following:

Hazard reduction The accumulation of litter and undergrowth in unburned forest stands increase the threat of wildfires. Such fires can seriously damage stands of all ages. Periodic prescribed fires reduce the liklihood of destructive wildfires.

Hardwood control Low value, poor quality hardwoods and shrub species often invade pine forests. They prevent successful pine regeneration and compete with the pines for available nutrients and moisture. A series of prescribed fires can be effective in minimizing this competition.

Site preparation Pines need bare soil and full sunlight to regenerate and grow. Fire helps to provide these conditions for natural regeneration. It also reduces the cost of site preparation by mechanical or chemical means when trees are to be planted.

Wildlife habitat improvement Many game and non-game wildlife benefit from prescribed burns. Predator cover is reduced, hidden seeds exposed for food, soil nutrients released and tdhe production of herbs and legumes is stimulated.

Disease control Certain tree diseases such as annosus root rot and brown spot needle blight of longleaf pine seedlings can be controlled by prescribed burning.

Improve accessibility Removal of excess underbrush by prescribed burning improves access and visibility. It aids in marking and cruising timber, harvesting operations and marketing timber.

To be successful, prescribed burning requires planning in advance. First, smoke sensitive areas near the burn must be determined. These are places where reduced visibility or smoke irritation to livestock and humans could cause material loss and suffering. Examples of smoke sensitive areas are airports, highways, communities, resorts, recreation areas, schools, hospitals, factories and stock barns. Do not burn if a sensitive area is within .75 mile downwind of burn. Wait for a wind from a different direction. Do not burn if area already has an air pollution or visibility problem. Burn only when virtical dispersion is good. Do not burn at night as temperature inversions and lack of wind holds smoke down. Visit the site to be burned to determine tree stand height, relative amount of fuel (leaves and needles or thick undergrowth) on the ground. Locate firebreaks where fuel and stand conditions change. Use roads and natural barriers where possible. County fire protection units will plow firebreaks for a nominal fee per hour.

The best time of year to prescribe burn an area is in the winter. Weather conditions are more predictable, stable and temperatures are usually cooler. Burn following the passage of a cold front when a steady northerly wind of 4 to 10 miles per hour can be counted on to dissipate the heat and smoke. Relative humidity should be beteween 30 to 50 percent. Forest litter should feel dry to the touch but the soil beneath should be damp. When relative humidity is lower than 30 percent, burning is very dangerous. Always confirm weather forecasts and check with the local Forestry Commission before burning.

Best Management Practices

The Federal Water Pollution Control Act of 1972 requires states to develop a program to protect and improve the physical, chemical, and biological integrity of the nation's waters so that they remain fishable and swimmable for every generation. Best Management Practices (BMPs) are guidelines to protect soil and water quality during ground disturbing activities such as forestry, agriculture, construction, and industrial operations. Each of these activities has their own set of BMP guidelines. The practices addressed here pertain to forestry and related silvicultural actions such as road building, stream crossings, timber harvesting, site preparation, reforestation, prescribed burning, fire suppression, fertilization, revegetation and stabilization of sites.

Many elements of BMPs have been incorporated into federal, state and local laws and regulations. Violations of these critical protective measures can result in prosecution and substantial fines. An example of a violation would be an activity that raises water temperature more than five degrees Fahrenheit which impacts fish habitat.

BMPs apply to state waters. According to Georgia law, waters of the state include all rivers, streams, branches, creeks, lake reservoirs, ponds, drainage systems, springs, wells,and other bodies of surface or subsurface water (natural or artificial) within or forming boundaries of Georgia. Waters that are entirely confined and retained completely upon the property of an individual partnership or corporation are not state waters.

Water quality protection begins with planning. The first step is identifying watercourses and water bodies such as perennial and intermittent streams, wetlands, sloughs or natural ponds. Stream type is important in determining level of protection that should be implemented. Topographic maps and county soil maps can help identify stream types, but where available, should be cross-referenced and field verified.

<u>Stream Types</u>

Perennial streams flow in a well-defined channel most of the year under normal climatic conditions. Some may dry up during drought periods due to excessive upstream uses. Aquatic organisms are normally present and easily found in these streams.

Intermittent streams flow in a well-defined channel during wet seasons of the year but not for the entire year. Water velocity is sufficient to move soil material, and aquatic life is difficult to find or not present in these streams. Topographic maps identify intermittent streams with blue lines separated by three dots. County soil maps identify them with black lines separated by two or more dots.

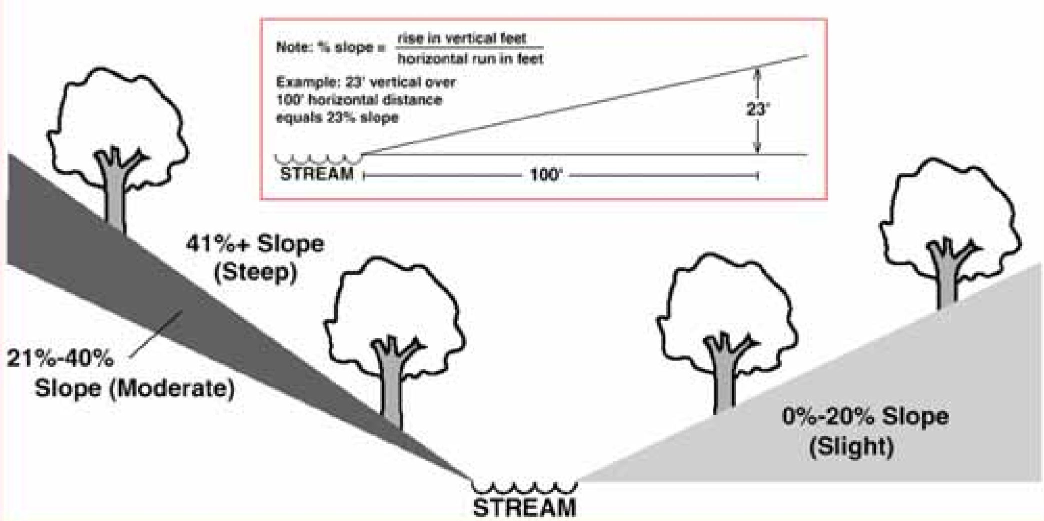
Ephemeral areas have water flows only after rainstorms. They are often referred to as drains, draws or dry washes and have no well-defined channel but do flow into perennial and intermittent streams. They are not usually identified on maps and do not support aquatic life.

<u>Streamside Management Zones (SMZs)</u>

Streamside Management Zones are buffer strips next to perennial and intermittent streams and other bodies of water to protect water quality. The SMZs provide cover to shade and regulate water temperature, provide natural filtration of sediment and pollutants, provide travel corridors for wildlife, flood protection and woody debris vital to the aquatic ecosystem. There is no uniform formula to determine the appropriate width of a streamside management zone. In general, however, the steeper the slope and more erosive the soil, the wider the SMZ.

Slope steepness should be determined from a point 100 feet perpendicular to the streambank. Therefore, SMZ widths may vary along a stream's course and on opposide sides of the stream. SMZs should be measured along the ground from the stream bank on each side of the stream and not from the centerline of the stream. After you determine percent of slope, check the chart by slope class and stream type to determine the width of the SMZ.

Figure 2-B. Diagram Showing How to Determine Slope



SMZ Widths by Slope Class and Stream Type			
Minimum Width in Feet of SMZ on Each Side of Stream			
Slope Class	*Perennial Stream*	*Intermittent Stream*	*Trout Stream*
Slight (less than 20%)	40 ft.	20 ft.	100 ft.
Moderate (21-40 %)	70 ft	35 ft.	100 ft.
Steep (greater than 40)	100 ft.	50 ft.	100 ft.

BMPs for Perennial and Intermittent Streams

Management activities may occur within an SMZ provided the disturbance to ground cover and the soil is minimized, water quality objectives are met, potential pollutants from the SMZ do not move into the watercourse and stream bank integrity is protected. These guidelines include:

- Adhering to local, state or federal regulations
- Determining and designating the appropriate SMZ width before conducting forestry practices
- Minimizing stream crossings
- Locating log decks, staging areas and skid trails outside the SMZ on well-drained, stable soils
- Installing firebreaks outside SMZs
- Minimizing intensity of prescribed fire in the SMZ to maintain forest floor cover
- Leaving at least 50% canopy cover along perennial streams after a harvest or an average of 50 square feet of basal area per acre evenly distributed throughout the SMZ to provide shade. (Basal area is the cross sectional area of a tree stand at breast height, including bark expressed in square feet per acre.) A prism is used to determine basal area.
- Leaving at least 25% canopy cover along intermittent streams after a harvest or an average of 25 square feet of basal area per acre evenly distributed to provide shade.
- Inspecting the SMZ periodically to evaluate the effectiveness of the BMPs and adjust practices when necessary.

Practices to Avoid within SMZs for Perennial and Intermittent Streams

- Cutting stream bank trees
- Unnecessary access roads and main skid trails
- Portable sawmills
- Soil compaction
- Removing ground cover or understory vegetation
- Mechanical site preparation or mechanical tree planting
- Felling trees into streambed or leaving logging debris in stream
- Servicing or refueling equipment
- Burning for site preparation
- Handling, mixing, or storing toxic or hazardous matereials (fuels, lubricants, solvents, pesticides or fertilizers)
- Broadcast application of pesticides or fertilizers

Some areas are considered sensitive and require more stringent protective measures. These include, but are not limited to, mountain trout streams, protected river corridors, water supply reservoirs/watersheds, ditches, canals, sloughs, wetlands braided streams, guillied areas and protected mountain tops. For trout streams, establish a 100-foot SMZ on both sides of the stream and its tributaries that includes one of the following choices:

Option A: A no-harvest zone within the first 25 feet of primary or secondary trout streams. Timber harvest in remaining 75 feet should leave 50 square feet of basal area per acre or 50 percent canopy cover.

Option B: Leave 50 square feet of basal area per acre evenly distributed throughout the 100-foot zone. This option can only be used if a qualified professional is consulted.

Most other sensitive areas are treated as perennial streams. Consult the Georgia's Best Management Practices for Forestry publication available through Georgia Forestry Commission, http://www.gfc.state.ga.us/ForestManagement/BMPmanual.cfm or a qualified professional for further guidance.

Any forest management activity, regardless of potential impact on water quality should be thoroughly planned. Plans need to consider:

- The history and past use of the land
- Sensitive areas
- Location, type, timing and logistics of each forestry activity
- Regulations or requirements superseding BMPs

The planning process helps to identify applicable BMPs, minimize environmental impacts, reduce costs, and preserve the long-term productivity of the land.

Whether the forest being managed is public, private, or owned by corporations complex economic, social and ecological factors have tremendous influence on forest management decisions. Some of these will be discussed in the next chapter.

Sustainability of Forests

Objectives

1. Define sustainability
2. Understand the role of technology in furthering sustainability
3. Distinguish between economic and intangible values of forests.
4. Understand sustained yield
5. Identify major insects and diseases affecting sustainability
6. Assess methods for controlling insects and diseases
7. Understand the consequences of global climate change on forest processes

What is sustainable forestry?

Sustainable forestry means managing our forests to meet the needs of the present without compromising the ability of future generations to meet their own needs. It means practicing a land stewardsip ethic which integrates the growing, nurturing and harvesting of trees for useful products with the conservation of soil, water and air quality as well as fish and wildlife habitat. The idea of sustainability means trying to do what nature does on her own—keep things in balance.

People have been part of this balance for thousands of years. It wasn't until the 20th century, however, that people had the machines and population growth to begin to throw things out of balance. We began taking away more than nature could grow back. We are trying to restore the balance by giving back to nature what we use. However, it is more than just a conservation issue, it is an economic issue as well. It makes sense for landowners to grow and use forests. However, if it costs too much for them to grow and maintain the forests, landowners may sell the forests for things like housing developments and shopping centers. When this happens, the timber base is lost as well as wildlife habitat, carbon sinks, and other ecological benefits.

Biology does not respect political borders and sadly, vice versa. The principles of ecosystem management argue for a geographic scale based on ecological boundaries such as watersheds. However, we must respect the reality that political borders may be more significant to management than ecological boundaries in achieving sustainability.

The characterization of sustainable forest management is a challenging task from a scientific as well as national and international policy perspective. Progress will be made step-by-step as countries gradually work within their own policies and opportunities to define the concept and measure the implementation of sustainable forest management. Many timber and trade organizations have adopted the goal of requiring all timber traded internationally to originate from sustainably managed sources. This is in response to many treaties and agreements. A "green" labeling or certification process has been developed to ensure forest products come from sustainably managed forests. There are four criteria integral to ecosystem management for sustainability: maintenance of biological diversity, viability of ecological processes, productivity of soil, water and air and the ability to provide for sustained human use.

Criteria for sustainable development operates from the premise that individuals and communities achieve an optimum level of self-sufficiency and improved quality of life by using only renewable natural resources which fall within their political and natural boundaries. A sustainable community is one which provides all of its own needs for air, water, land, food, fiber, and energy resources within its own boundaries. Much study has been devoted to determining how much use or development is sustainable. There are many variables to consider and agreement must be reached on what is acceptable. Scientists and laymen do agree on the indicators that signal when we are achieving sustainability and when we are not.

Sustainable Indicators

Air One can live only two to three minutes without oxygen. Air quality is a critical indicator to human and planetary health. Considering the evidence of rising carbon dioxide levels, ozone depletion in the upper atmosphere, and global climate change, we can no longer presume that the air we breathe indoors and out is a renewable resource. Balancing the community's carbon dioxide to oxygen exchange is a critical indicator of a sustainable system.

Water One can live only two to three days without liquid. Humans require only approximately one to two gallons of water per day, yet we consume an average of 150 gallons per day for indoor and outdoor household use per person. Modeling the input and output of water resources of a site provide another challenging indicator for sustainability.

Land, food and fiber One can live only two to three weeks without food. Food and fibrous materials used for clothing, shelter, and paper are essential to sustenance and enjoyment. The three R's – reduce, reuse, and recycle—are useful concepts for sustainability. Total sustainable strategies would produce no need for disposal. Today's wastes would become resources to be reused and/or recycled. Precycling (buying only goods that can be recycled) helps reduce waste and consumption of valuable renewable and nonrenewable resources. Buying products made from recycled content is also critical to sustain the economic viability of the system.

Energy Energy is the primary agent of change in ecological systems. Sustainability can be modeled by a site or society's percentage use of renewable versus non-renewable energy resources. Full sustainability would require a site or society to completely shift to renewable energy systems.

Human ecology People define the final and most inclusive indicator. The degree of commitment and action programs toward a sustainable future is critical in modeling this variable . People can determine the existing use of each resource, the non-renewable and renewable supply of each of the resources on a “site” and the estimated percent of conservation required to place each human-influenced environmental system in balance.

New technology will be able to help as communities, agencies and organizations recognize how collective actions affect each other and partner to solve problems. Technology allows research and alternatives to be modeled to see how well they work and how they interact before large investments are made.

Technology in Forestry

People use the forest for many purposes, including recreation and providing drinking water, habitat for wildlife, and timber for wood and paper products. To sustain these benefits it is important to evalulate all possible effects of forest management on the ecosystem. Forest management requires roads and trail systems to provide access for all uses. It also requires choosing a way to grow future forests. Computers and satellite technology help forest managers make decisions which meet human needs without harming the ecosystem. Computer applications are used to model the effects of different management activities. Computers even help determine the economic value of standing timber.

To estimate the value of standing timber, measurements of sample plots are taken throughout the forest. This is called *timber cruising*. Every tree within the plot is measured, either by hand or estimated with the eye. It takes years of practice to accurately measure trees with your eyes. After trees within a plot are measured, they are then multiplied by the number of acres inventoried. This creates a “blow-up” effect, which allows you to get an idea of what is there without actually measuring each and every tree in the forest. The larger the plots and the more measurements you take, the better the estimate of the true value of the timber.

<u>Global Positioning Systems</u>

Global Positioning Systems (GPS) are navigational tools developed, by the U.S. Department of Defense and made available for civilian use in a less precise mode than that available for the military but far more precise than any previous technology. Networks of orbiting satellites (constellations) provide 24-hour, three-dimensional position, velocity and time information to special receivers anywhere on or near the surface of the Earth (and sometimes off the Earth). The constellation consists of 24 satellites, 18 of which should be operational at any one time. They orbit the planet at an altitude of 20,000 -26,000 km in an elliptical path with 4 satellites in each of six orbital planes. It takes 12 hours for a satellite to orbit the earth once. The height of the orbit means that they are not affected to a great extent by the Earth's gravitational field and the effect of the sun and the moon on the GPS orbits are modelled as systematic errors. The satellites transmit the main positioning codes at two radio wave frequencies that minimize the effect of the ionosphere and troposphere on the transmitted signal.

The GPS unit must receive signals from at least four satellites to give an accurate reading. The receiver calculates longitude, latitude, altitude, travel direction and speed. Data are collected digitally, making storage and retrieval easier. Commercial hand-held GPS receivers can determine positions to within ten feet.

Geographic Information System (GIS)

Information collected about the nature, condition and location of Forest resources, such as timber, vegetation, soils and archaeological data is managed using a Geographic Information System (GIS). A GIS is an information system used to input, store, retrieve, manipulate, analyze and output geographically referenced or geospatial data. It aids decision making, planning and management of natural resources, land use, transportation, facilities and administrative records. After data is collected in the field and its location recorded on a GPS receiver, the information is downloaded to a computer. The computer mapping system then interprets the data and plots it on a statewide map, topographic map or other device. This allows the user to see how the data collected whether it be cultural resources, rare and endangered plants, streams, rivers, timber types, etc. is distributed across an area. The information is most often digitally overlaid so each data set can be studied separately, or viewed as a whole.

The most valuable aspect of GIS is that it helps managers make more informed decisions. For example, a certain endangered species may need a 500-yard undisturbed radius around its nest. The forester wants to plan the best possible route for a logging road through the area without disturbing the animals. The GPS data is collected on nest locations and where the road needs to begin and end. GIS plans the route within the 500 yard constraints that the user sets to protect the species. This saves hours of work and money by optimizing all resources.

Economic and Intangible value of forests

The economic value of forestry to Georgia is tremendous. The Georgia forest industry directly and indirectly employs over 100,000 people. Timber is the highest valued crop produced in Georgia. The forest industry also creates value-added products to the forest economy and primary manufacturing industries. For example, Georgia has the largest recycled paper manufaccturing industry in the southeastern United States. Recycling paper adds value to the trees as it extends the amount of produccts derived from trees. Second and third tier manufacturers dependent upon the forest industry are also located in Georgia. These include furniture manufaccturers, mobile home plants, box and bag plants, computer paper makers, diaper, toilet paper, napkin and many other manufacturers supplying products for final use by consumers and businesses. There are literally over 5,000 products that come from trees that we use every day as we have discussed earlier.

The intangible benefits Georgia's forests provide that contribute to the quality of life are also often overlooked. The forests help clean the air, and water, buffer noise, provide recreational benefits, wildlife habitat, and serve as a carbon sink by fixing carbon dioxide from the atmosphere. It is difficult to calculate these values in terms of dollars and cents. Consider the following:

An acre of trees can store 2.6 tons of carbon each year. This can compensate for automobile fuel use equivalent to driving a car between 7,200 and 8,700 miles based on the fuel efficiency of the vehicle.

An acre of trees can remove between 287 and 651 tons of sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone and particulate matter per year. Pollution removal varies based on weather, canopy cover, length of growing season and pollution concentration.

An acre of trees will provide about 2.8 tons of oxygen per year. This is enough for 14 people.

Tree cover over pervious surfaces can reduce runoff as much as 40 percent and reduce the costs of treating stormwater runoff by decreasing the volume of water handled during periods of peak rain events.

Energy use in a house with trees can be 20 to 25 percent lower per year than that for the same house in an open area.

Wide belts of (30m) tall dense trees combined with soft ground surfaces can reduce noise by 50 percent (6 to 10 decibels).

Trees provide wildlife habitat. Wildlife can serve as biological indicators of changes in the health of the environment.

Aesthetic values such as the beautiful colors of fall displayed in the north Georgia mountains brings thousands of tourists to the area each year. These visitors spend millions of dollars while enjoying the recreational opportunities. Without this draw, many businesses would not survive in this area of the State.

Economic development based on degrading the natural resources cannot be sustained. Neither can environmental protection be ensured unless people's basic needs and wants are first satisfied. There must be enough productive resources including people, capital, and natural resources to produce all the products such as cars, health care and the ecological quality we want. Careful management, however, goes a long way toward providing most of these needs and wants including environmental quality.

Georgia's forests are important for jobs, for production of goods we need and use every day, and to protect the health of the environment and ourselves. Conservation of these resources through both forest management and individual stewardship is essential.

Sustained Yield

Is it possible to preserve forests and cut them down at the same time? If they are carefully managed at a sustainable rate of harvest, the cycle of harvesting, replanting and growth can go on forever without running out of trees. For years, foresters have practiced the principal of sustained yield. Sustained yield is the rate at which a resource may be used without reducing its long-term availability or limiting its ability to renew itself.

For example, there is a Christmas tree farm made up of four different areas. The trees in each area are five years older than the trees in the area next to it. The trees in plot **A** have just been planted; the trees in plot **B** are 5 years old, the trees in plot **C** are 10 years old and the trees in plot **D** are 15 years old. The Christmas trees in plot D are mature and ready to be harvested for the holiday season. No others are harvested. Once plot **D** is harvested, seedlings are replanted. A harvest of each plot can be done every 5 years without running out of trees.

Another example is to assume this Christmas tree farm contains 4,000 trees. Each year you want to cut 20 percent of them (800) trees and replant 1,000 trees each year. Will the Christmas tree forest eventually disappear? Will it stabilize? If so, in how many years and with how many trees? *Answers:* The forest will not disappear given stable soil, water, climate, and biological conditions. Planting back 1,000 trees increases the forest by 200 trees per year. The entire forest will be cut over once in 5 years with a harvest rate of 20 percent per year. But, since 1,000 trees are being replanted each year, at the end of 5 years you will have a gain of 1,000 trees.

The forest will stabilize after 5 years at 5,000 trees and will have a balance of age classes or an equal number of trees in each age class. The long term sustained yield capacity will also have been reached in 5 years assuming the growth rate cannot be changed by changing species, genetic selection for more rapid growth, fertilization or thinning.

The same principles are applied to tree farms for forest product production. It is similar to planting and harvesting a garden. The key is to control the rate of harvest to insure a continuous supply for present and future generations.

<u>Sustainability Case Study</u>

John inherits a 1200-acre farm in the Georgia piedmont. Farm records show the land uses are:

120 acres of grass for pasture or hay
50 acres of cultivated row crop land
20 acres of water in three ponds
10 acres with the farmhouse, garden, orchard and barns
1,000 acres forested

Of the 1,000 acres, 60 percent (600 acres) are loblolly pine forest type, 35 percent (350 acres) are oak-hickory forest ype, and 5 percent (50 acres) are bottomland hardwoods along a major creek at the back of the farm.

John wants to keep the farm in the family, make an annual income great enough to pay the taxes and routine maintenance and use the farm as a family retreat. Taxes are $8,000 per year, and handyman/yard service $100 per month so John will need $9,200 annual income from the farm to take care of these expenses. Potential income could be:

120 acres hay field @$15 per acre	$1,800
50 acres of renting row crops @$30/acre	1,500
1,200 acres hunting club lease @$5/acre	6,000
Total	$9,300

This could meet John's need for expenses, but John does not want to lease the forested land to a hunting club. He wants the wildlife there to be relatively unafraid of humans and doesn't want to worry about timing visits to avoid seasons or hunters. He wants a safe play environment for his children, good wildlife habitat for medium to high populations and diversity of wildlife including non-game species. He wants a scenic forested area for hiking, picnicking, bike riding, wildlife watching, photography and other recreational activities. He wants clean water in the ponds and creek and undisturbed forest along the creek which is a special place for him because of memories of fishing there with his grandfather. He wants a forest that is healthy so that insects or disease do not threaten his other goals.

John consulted a forester. The forester inventoried the kinds of trees, their ages, how many stems are there per acre, their growth rates, their quality, and how well-suited they are to the ecological conditions of the land on which they are growing. A map is made of the forest types that are alike and the information summarized as follows:

Age Class	**Acres of Pine**	**Acres of Hardwood**
0-10	90	0
11-40	300	105
41-80	180	160
80+	30	35
Total	600	400

The forester also found that the 35 acres of hardwood in the over-80 age group are bottomland hardwoods along the creek. The remaining 15 acres of bottomland hardwood are also along the creek but are in the 41-80 year age class. Most of the 90 acres of 0-10 year old pine type is the result of a Southern pine beetle outbreak which killed the older pine on these areas. These 90 acres were salvage harvested by local loggers. John's grandfather had reforested these areas and they had young, fast-growing loblolly on them.

Based on the knowledge of timber markets, local wood industry and tree growth the following recommendations were made:

1. No harvest in the 35 acres of 80+ year old bottomland hardwood to meet John's goal of preserving it as a special place.
2. Thin the entire 11-40 year age class, both pine and hardwood with the first harvest in the current year. Favor the best trees to grow for the future. In the hardwoods, favor the nut-bearing oaks and hickories as the trees to be left and protect existing den trees from cutting or logging damage to meet wildlife habitat goals. The estimated income for both pine and hardwood thinning is $70 per acre. This harvesting should be spread over 7 years by thinning 100 acres every other year. This thinning provides needed current income, provides for future increased revenue, reduces risk of insect attack and provides wildlife habitat. (Income: $7,070 for each thinning)
3. Harvest 20 acres of pine 80 years old or older every 5 years by the seedtree method, leaving 8 to 10 trees to reseed the area and start a new forest. After the first seedtree harvest in the current year, seedtrees would be removed every 5 years as a new seedtree cut is made. These harvests remove the trees most likely to be killed by the Southern pine beetle, minimizes reforestation costs and provides a steady supply of shrub-weed type habitat for wildlife. Gross income for the first cut should be about $750 per acre and $200/acre five years later at seedtree removal. This amount of harvest should be maintained on the same schedule indefinitely. (Income: $15,000 first year, and $4,000 for each seedtree removal cut.)
4. Defer any harvest in the 41-80 year old hardwoods for at least 10 years or until objectives change, then re-evaluate.
5. Keep 10 acres of 80+ year old pines, which is around one of the ponds, as a family recreation area unless it is attacked by beetles, in which case a clearcut and conversion to oak-pine type could be made through planting pines at wide spacing and allowing stump sprout regeneration of oak and hickory.
6. Buffer the large creek during thinning harvest with a 100-foot, no-harvest zone. Buffer all other streams with a 50 foot wide no-harvest zone on each side of the stream to filter runoff from upslope.
7. Require the logger to reseed log landings and skid trails with grass and legume seed mix for wildlife and to prevent soil erosion. Re-evaluate management plan, objectives and results every 5 years and adjust as necessary due to changed conditions.

The recommendation to seedtree harvest 20 acres of 80-year old pine every 5 years is sustainable since only 40 acres will be harvested every 10 years and each age class has at least 45 acres. Then a "new" set of acres will age into the 80-year old class in time for the next scheduled harvest. John's income will be periodic rather than annual. Once the thinnings end, income will come in only every 5 years, so John will have to save and budget for expenses that occur during the years he has no revenue from forestry.

What are the diseases and insects affecting Georgia's forests?

There are hundreds of diseases and insects that kill and damage Georgia's hardwoods and pine forests each year. Several will be described here.

<u>Southern pine beetle</u> This insect is of utmost concern to homeowners, foresters, landscapers, builders and recreation managers. It wipes out acres of southern pines when conditions are favorable. These beetles occur not only in Georgia but throughout the south and even Central America.

Adult beetles are about the size of a grain of rice and reddish-brown in color. They mate, bore diectly through the bark, and the females begin to excavate S-shaped egg galleries in the inner bark. The eggs hatch into legless grubs within four to nine days. The grubs mine for a short distance and pupate in the outer bark. There are three to seven generations per year depending on locality and weather. Drought seems to be associated with major outbreaks of the beetle. Control includes rapid salvage of infested trees where possible. Felling trees in a circular plot toward the center seems to disorient the beetle so it starves before it can reach healthy trees. Piling and burning of infested material also seems to help diminish beetle outbreaks.

<u>Bagworms</u> These wingless, maggot-like adult female bagworms are present in September and October and spend their entire lives in the silken bag they construct as larvae. Males fly around infested shrubs in the fall searching for a mate. Mating takes place through the open end of the bag. The female then deposits an egg mass of up to 1,000 eggs in her pupal case. They begin hatching in April and defoliate conifers and even many hardwoods including Wild cherry, poplars, oaks and apple trees. Cold temperatures reduce their numbers. Homeowners can control by handpicking bags and destroying them.

<u>Gypsy moth</u> The Gypsy moth was brought to the U.S. from Europe in 1869 and has spread from the northeastern states to the north Georgia mountains. It defoliates both hardwoods and conifers. Full grown caterpillars measure more than two inches and are identified

by five pairs of blue spots and six pairs of red spots in a double row along the back. Adult moths are active from June to September and the females rely on sex attractants to lure male moths. Thousands of dollars have been spent on methods to control this insect including fake sex attractants and introduced parasitic predators. The greatest problem in controlling the insect is the fact that recreational vehicles transport egg masses and larvae from infested to uninfested areas.

Ips engraver beetle With the exception of the Southern pine beetle, no other insects cause as much mortality to the southern pine forests as the Ips engravers. They usually attack weakened trees, lightning-struck trees or green slash left by logging operations. During droughts they can successfully attack healthy pines. The Ips quickly girdle the tree as they build their egg galleries in the inner bark. Death is usually hastened by the introduction of blue-stain fungi which blocks the flow of sap. Small reddish pitch tubes are on of the first signs of attack. Peeling back the bark will reveal the typical Y or H shaped galleries extending perpendicular to each side. Ips beetles have "scooped out" posteriors surrounded by varying numbers of tooth-like projections.

Hemlock wooly adelgid These tiny aphid-like, sap-sucking insects threaten the Eastern hemlocks that grow mostly in the southern Appalachians and along stream banks. Adelgids inject a toxic saliva into the youngest branches of a hemlock where the needles attach to the twig interfering with the hemlock's ability to produce new growth. The Hemlock wooly adelgid spends most of its life in a white wooly eggsac the size of a Q-tip. Newly hatched crawlers search for new places to settle and feed. Some develop into wingless adult females that stay on the tree to produce another generation and others become winged adults that fly off to find another host plant. Infested hemlocks must be completely drenched with any one of a number of registered pesticides usuing hydraulic spray equipment. Biological control is showing promise in destroying this pest.

Fusiform rust Fusiform is one of the most important diseases of southern pines. It is recognized by the spindle-shaped canker on the pine branches or main stem. In early spring, these swellings appear yellow to orange as the fungus produces powdery spores. As the host tissue is killed, older stem cankers become flat or sunken. Cankers often girdle trees. Fungus spores from the pine infect oak leaves. Brown hair-like structures produced on the underside of oak leaves in late spring, reinfect the pine trees completing a "rust" cycle. Cutting out seedlings with galls and pruning infected branches will reduce the incidence of this disease.

Red heart Red heart disease occurs in mature conifers. The fungus attacks all species of mature pines in the south. Infection occurs through dead branch stubs. Advanced stages of heartrot appears as elongated white pockets or flecks, formed parallel to the grain and separated by firm wood. Control is limited to harvesting mature and overmature pines where woodpecker habitat is not a consideration. Trees can be somewhat protected by pruning dead and dying branches on the main stem to minimize infection. The goal in pruning is to allow the knot to be quickly overgrown by sapwood thus preventing the fungus from entering the branch stub.

Dogwood anthracnose Dogwood anthracnose causes leaf spots, stem cankers,and kills shoots of infected trees. Initial symptoms are purple-bordered leaf spots and scorched tan blotches. These may enlarge to kill the entire leaf. Blighted leaves often cling to stems after normal leaf drop in the fall.

Trunk sprouts occur during the later stages of Dogwood anthracnose development. The fungus infects twigs and can grow down a limb and infect the main stem. Cankers can form on the main stem detected when bark is peeled back. Dogwoods adjacent to natural stands of the species are more susceptible. Prune dead wood in the tree before the disease reaches the main trunk. Destroy the pruned wood to eliminate infection. Improve air circulation around tree and to help dry foliage and reduce infection.

Chestnut blight Chestnut blight is caused by the *Endothia parasitica* fungus. It was introduced when the Chinese chestnut was imported to this country in the early 1920's. The fungus wiped out the American chestnut in Georgia and throughout the southern Appalachian mountains. The fungus survives in previously killed stumps and later kills the new sprout growth. The Chestnut blight fungus is also parasitic on chinkapin, Spanish chestnut and Post oak. Japanese and Chinese chestnuts are resistant.

Pesticide Use in Forestry

Pesticide use in forestry can be controversial. However, pesticides have enabled us to increase crop yields, including timber, on an ever shrinking land base to meet the demands of a growing population. The three primary groups of forest pesticides are herbicides (which kill plants), insecticides(which kill insects) and fungicides (which kill fungi).

Purpose of pesticide use in forestry

1. To protect forest visitors (fire ants, poison ivy)
2. To protect trees, tree seeds, and wood products from damaging insects and diseases, especially in nurseries.
3. To prepare land for planting or seeding by removing competition for space, water, and nutrients.
4. To maintain survival and growth of those trees which best meet management objectives.

Herbicides

Herbicides are the most widely used category of pesticides for forestry. Georgia and the southeast are well-suited for the commercial production of pines used for lumber and paper. When herbicides are used here, it is usually for site preparation before planting pines and to prevent hardwoods from taking over the site once pines are established.

Another management objective may be to preserve habitat for wildife and endangered species. For example, the endangered Red-cockaded woodpecker favors live Loblolly and Longleaf pines infected with Red-heart disease to nest. Encroachment of hardwood brings predators and causes the woodpeckers to abandon the site. Herbicides are sometimes used to preserve the park-like stand for these woodpeckers.

Pesticides used on the National Forest are applied so they do not harm wildlife such as deer, squirrels, bear, fish, etc. The target species for herbicides are usually 5-7 year old hardwoods on a site managed for high quality pines. These hardwoods are not part of wildlife diets when the hardwoods have reached that size. Once the competing hardwoods die, forbes such as broadleaf weeds, wildflowers and berries grow in their place, increasing the food supply for a greater diversity of wildife and beneficial insects.

Insecticides

Insecticides are not widely used in forestry due to the large areas of application needed to control the insects. The cost and environmental concerns associated limit these applications. One exception is aerial spraying for Gypsy moths in north Georgia with *Bacillus thuringinsis* (Bt). Bt is a naturally occurring soil bacterium that kills Gypsy moths. Unfortunately, it also kills certain beneficial caterpillars such as the Monarch butterfly.

Fungicides

Fungicide use in forestry is mainly limited to single stem applications for high value trees. The life cycles of fungi coupled with their ability to generate large amounts of spores can make their control almost impossible. Fortunately, with the exception of the Chestnut blight, our forests have not been hit with major losses from fungi.

Methods of Application

There are two man categories of applying pesticides in forestry:

1. Broadcast methods such as aerial or ground spray units cover larger sites and are generally quick and cost effective.
2. Selective methods such as basal soil treatments (also known as spotgun or grid), thinline, injection, cut surface and backpack directed sprays are also commonly used in the southeast. Selective methods use less herbicides and place it only where needed. It is more flexible by combining methods and controlling only the species treated. Selective methods are considered more environmentally sensitive and are the only methods of herbicide application used on the National Forest. One disadvantage is that selective methods are labor intensive which can make them expensive.

Regulations and Safeguards

It is illegal to apply a pesticide in a manner inconsistent with its label. A label is more than the sticker on the package. It is the document which contains the information needed to correctly apply a pesticide. It is important to note that the rates listed on a label may not be exceeded but may be reduced. In many areas such as the National Forest, pesticides are used at the lowest effective rates, applied selectively or combined with integrated pest management (IPM). For example, where herbicides might be applied on the National Forest to control hardwood competition, only 20% - 30% of the stems would be treated. Plants or animals of special concern, water and adjacent woods are buffered with untreated areas.

In addition to the pesticide label, the Material Safety Data Sheet (MSDS), is a very important document. The MSDS should be available to anyone handling a pesticide. It contains information on health hazards, first aid, disposal, ingredients and physical data.

In Georgia, to apply pesticides you must have a pesticide applicators license to purchase and apply restricted-use pesticides. When applying forest pesticides for hire, you must have a Commercial Pesticide Contractor’s License, Category 23 and a Pesticide Contractor’s License.

Integrated Pest Management

Reliance on chemical pesticides in forestry has declined in some areas due to an integrated pest management approach (IPM). IPM uses biological control, prescribed burning, various silvicultural methods, and salvage harvesting as alternative ways to control pests. Integrated pest management assumes a certain level of pests is tolerable and can combine control techniques, including chemicals, to achieve successful results. When chemical pesticides are used, they are applied when the pests are vulnerable. This decreases the volume of chemicals needed and helps preserve diversity of the ecosystem. An example of IPM is prescribed burning to control Brown spot needle blight (a fungus) on longleaf pine and salvage cutting of Southern pine beetle infested trees. Pines infested with the beetle and a buffer of green pines are felled toward a center point. This disorients the beetles and they starve before they can be carried by the wind or crawl to another stand. If the trees are cut soon after the infestation begins (3-6 months), they can be salvaged for pulpwood. If not, the trees should be burned in a prescribed burn to kill larvae and prevent further spread of insects.

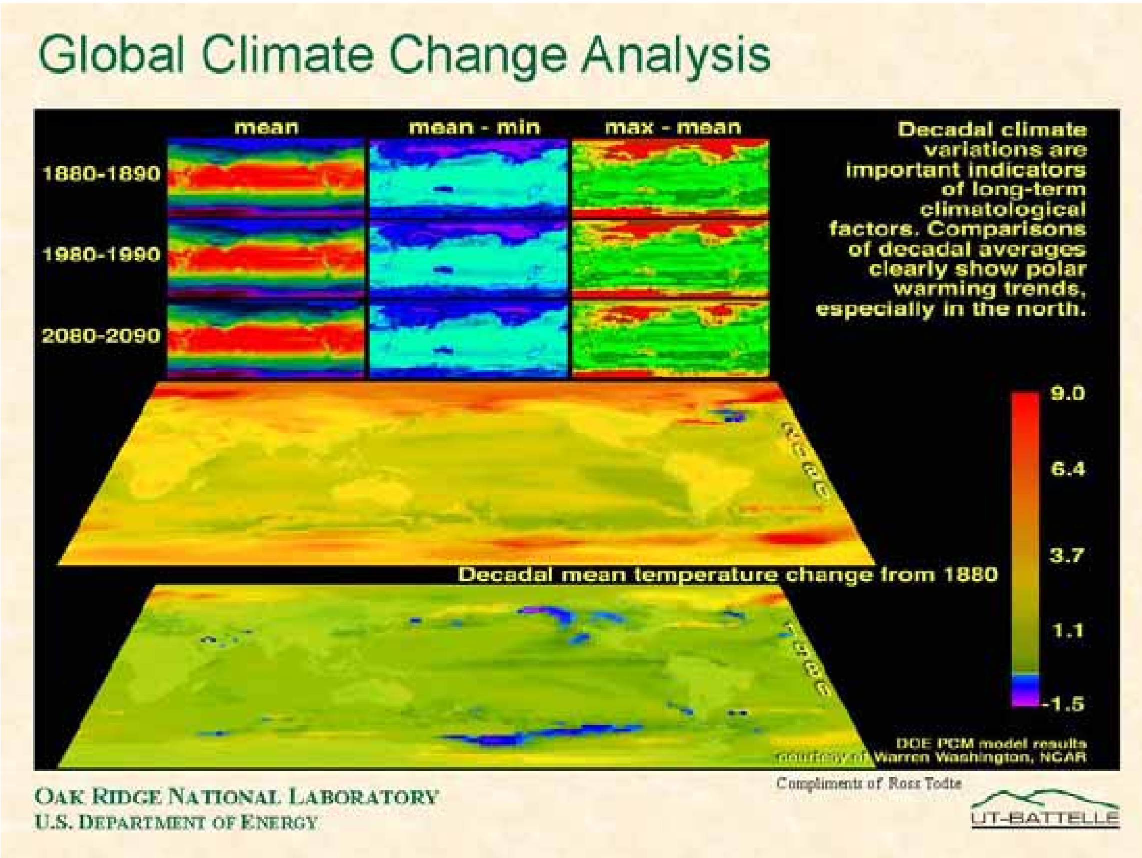
Another example of IPM is biological control such as releasing sterile insects into an outbreak of pests or increasing the habitat for or attracting the natural enemy of the pest. Research continues in IPM to reduce the use of pesticides, especially insecticides. Recent studies have discovered a natural repellent, 4-Allyanisole (4aa), in the resin of pines. The development of compounds like 4-aa hold great promise for the further reduction of pesticide use in the future.

Integrated pest management seeks to work with nature to control pests. It offers the best alternatives for preserving our natural resources and sustaining the ecosystems that support us.

Global Climate Change and Variability

Earth’s climate has been changing constantly over its 5-billion year history. We have scientific evidence that oceans once covered much of the continents and that the end of the ice age caused tremendous species extinction. These climatic changes happened very slowly, over a period of thousands and even millions of years; whereas, the changes occuring now are happening much more rapidly.

Forest processes are critical to providing clean air and water, moderating stream flows, and maintaining aquatic habitats. These processes control responses of forests to environmental factors. Several environmental factors are changing rapidly and at the same time that affect biodiversity, agricultural crop production, water resources and the health of forests. Carbon dioxide (CO_2) concentration has increased by 30% since the late 1800s and could double in the next century. Harmful ground level ozone has increased while the stratospheric ozone has so severely thinned over many parts of the globe, it is termed holes in this layer that shields ultraviolet radiation. The average global temperature has increased an average of 1 degree Fahrenheit over the past century and some climate models project an increase between 2.5 and 10 degrees Fahrenheit over the next 100 years. Sea levels have risen 6-8 inches worldwide over the past 100 years and could rise 3.5 – 35 inches in this century. Even variations in temperature from decade to decade correlate with increases in extreme weather conditions such as drought, floods, snowfall, heatwaves, etc. in different locations over the globe.



Field experiments and modeling indicates forest productivity increases with the fertilizing effect of carbon dioxide. However, it is short-lived when water and mineral nutrients limit plant growth. Modest warming stimulates carbon storage in most forest ecosystems, however, greater warming leads to drought and carbon loss which is made worse by increased fires. Current ozone levels have offset wood production 5 percent in southern pine plantations. Ozone also changes fertility of the soil and ability of plants to uptake nutrients.

Over the past 30 years hundreds of acres of Southern baldcypress, Sabal palm and Live oaks have died as a result of rising saltwater levels as much as 30 miles inland in the Gulf states. Coastal forest losses will be even more severe if sea-level rise accelerates as is expected with global warming.

Water resources and hydrologic processes are tightly coupled with ecosystem dynamics and forest carbon cycle. With increased temperatures, longer growing seasons and greater leaf area, forests may transpire more water. Increased transpiration reduces runoff, affecting other uses of water. Shifts in runoff could severely stress water resources in different locales.

Climate variability and changes can alter the frequency, intensity, timing, and spatial extent of disturbances such as tornadoes, hurricanes, ice storms, droughts, fires, landslides, disease, insect infestations, etc. in forest succession. This in turn, can have significant ecological and socioeconomic impact. Some of these include habitat for cold water fish species would decrease while warm water fish species increase. Recreation values and economies that depend on these will be affected such as camping, hiking, leaf watching, and snow skiing. For example, snow-skiing opportunities could decrease with fewer cold and snow days, necessitating the making of artificial snow which increases both water and energy use. Warmer lowland temperatures will attract people to higher elevations putting even more demand on mountainous areas for human habitat and altering the ecological processes that take place there.

Virtually all scientists directly involved in climate change research agree that most of the warming is attributed to increased emissions from the burning of fossil fuels. Many people do not consider even an extreme global warming of 10 degrees to be a problem, as humanity has always had severe weather events, species extinction, wars over resources, etc. Perhaps a different perspective is understood when one realizes that during the last ice age, some 18,000 years ago, the global temperature was only 7 degrees cooler than it is now.

Urban Forestry

Objectives

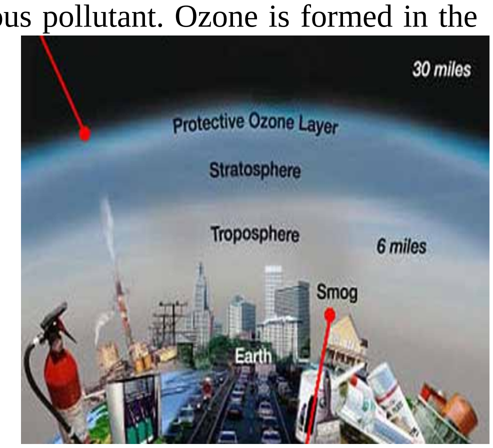
1. Define urban forestry.
2. Describe challenges to trees in an urban environment.
3. Identify tree species appropriate in an urban environment.
4. Know how to assess the health of an urban ecosystem.
5. Describe patterns of urban growth.
6. Identify ways to protect trees during construction.
7. Understand the value of trees in urban and suburban settings.

What is urban forestry?

Urban forestry is the planting, care and management of trees and tree benefits in a community. The urban forest is an ecosystem of all the trees, wildlife, associated vegetation and other natural resources along a street, in open green spaces, parks, commercial and private properties in a city, town or community. People influence the health of the urban forest more than any other ecosystem.

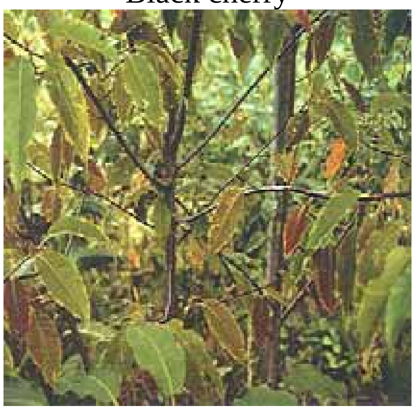
Growing large trees (trees with a crown diameter of 20 feet or greater) in most urban areas is difficult because soil conditions are usually poor, there is limited growing space, urban temperatures are elevated, pollution is usually greater and trees in the city receive more physical abuse. Damage to trunks from lawnmowers, cars, and people carving their initials causes wounds which make trees more susceptible to insect and disease attacks. Overhead wires and underground utility pipes restrict growing space. The compaction of the surface soil, air and soil pollutants, road salt and exposure to harsh wind and heat reflected from concrete are additional problems. Trees under stress can also become hazards if not properly maintained. The average tree in the city lives 32 years but a tree in the downtown area may live only 7 to 10 years. The same tree on a rural site might live 200 years in the absence of development stress.

An additional challenge of growing concern affecting the health of trees is ozone. While the earth needs a protective layer of ozone in the stratosphere to block harmful solar radiation, in the lower atmosphere it is a serious pollutant. Ozone is formed in the air by a reaction of hydrocarbons and nitrogen oxides with sunlight. These chemicals are released into the atmosphere primarily by the burning of fossil fuels for transportation or power generation. Ozone is the most widespread air pollutant in the United States.



Ozone is a gaseous molecule having three oxygen atoms as opposed to the normal state of oxygen consisting of two oxygen atoms. It has a distinct odor and is found in small amounts when ordinary oxygen is struck by lightning. It can be made in laboratories with electricity. Ozone is highly reactive and because of its unstable state, the molecule splits easily into ordinary oxygen and an extra oxygen atom. This lonely oxygen atom quickly oxidizes whatever comes across it; therefore ozone is a strong oxidant useful in purifying water and harmful impurities. The problem with ozone is that when it comes into contact with living matter whether it is a plant leaf or a human lung, it reacts violently, causing cell damage. In plants, ozone inhibits photosynthesis and growth. The pictures below show what ozone damage looks like on common species found in Georgia.

Black cherry



Yellow poplar

Loblolly pine

Volatile organic compounds (VOCs) and nitrogen oxides that form ozone come from both natural and human activities. Isoprene, which is the largest of the VOCs from natural sources is highly reactive and one of the most effective in producing ozone. At room temperature, trees emit VOCs; one of which is isoprene. Natural VOC emissions increase with higher temperatures and intense sunlight. Trees in urban areas can reduce the urban heat island effect which decreases the acceleration of VOC emissions. Trees planted directly around structures can reduce air conditioning needs which in turn, reduce the amount of VOCs released at power plants.

Deciduous trees have higher emissions than evergreens but large evergreen forests can have significant emissions. Sweetgum, oak and poplar trees native to Georgia emit high levels of isoprenes. Other species such as magnolia, pine, ginkgo, maple, hickory, dogwood, alder, beech, sourwood, birch, holly, mulberry, redbud, cherry, sassafras, and elm are low emitters. These trees should be seriously considered as replacement trees and trees to be protected during construction in urban areas if you are managing for air quality benefits.

Because of these natural emissions, some ozone is present even in the absence of human activities. Scientists estimate that an average natural ozone concentration is 25 to 45 parts per billion. This is much lower than the current ozone standard of 125 parts per billion. Thus, natural emissions by themselves would not cause unhealthy ozone levels. The main contributors to high ozone levels are from the burning of fossil fuels for transportation or power generation.

What trees area appropriate for urban settings?

Trees enhance the beauty and value of a home, street, and a city. However, planting a tree in the wrong place can cause property damage and become a detriment rather than an asset. A few minutes carefully planning the type of tree to plant and where to plant can save thousands of dollars in the long term.

When selecting the tree, there are several questions you should answer.

1. First, determine why the tree is being planted. Do you want the tree as shade, screening, spring flowers, fall color, to frame your house or landscape, to help manage stormwater runoff, or simply to have something green.
2. How large will the tree ultimately become? Will it still fit into your yard or streetscape when it is mature? Will the tree form an upright, round or spreading type crown? A dangerous traffic situation is created when tree limbs screen traffic lights, street signs or your own driveway. Trees often cause electrical problems either by limbs rubbing on wires or large limbs falling on lines. A tree planted too close to a sidewalk, driveway or house foundation can lift and break a large amount of paving. A minimum of 6 feet from curb to sidewalk is recommended for small trees. A shallow-rooted tree will often clog sewer lines. Remember the root system of a tree needs as much area as the above ground portion occupies in the air.
3. Will the tree bear objectionable fruit or produce seeds that will litter the ground?
4. Will the tree be able to survive the local climate and pollution conditions? Is the wood strong enough to bear loads of ice and wind without breakage?
5. Will the tree fit with your architectural plans, and how will it affect your neighbor's property?
6. Is the tree a low emitter of volatile organic compounds (VOCs) if ozone is a concern in the community?
7. Is the tree native to the area? Native trees usually require less maintenance and are more likely to thrive.

<u>Recommended Small Trees </u>(15 to 25 feet tall at maturity, these trees may be planted near electric lines)

Flowering dogwood (*Cornus florida*)*
Eastern rebud (*Cercis canadensis*)*
Flowering crabapples (*Mallus species*)
Crape myrtle (Lagerstroemia)*

<u>Recommended Medium Sized Trees </u>(25 to 50 feet tall a maturity. Do NOT plant within 30 feet of electric lines)

Carolina cherry laurel (*Prunus caroliniana*)*
Japanese maple (*Acer palmatum*)*
Sourwood (*Oxydendrum arboretum*)*
American holly (*Ilex opaca*)*

Recommended Large Size Trees (50 feet or more at maturity. Do NOT plant within 50 feet of electric lines)

Southern magnolia (*Magnolia grandiflora*)*
Pin oak (Quercus palustris)
Live oak (*Quercus virginiana*)
Ginkgo (*Ginkgo biloba*)* *Plant only the male tree as the fruit or seed of the female gives off an objectionable odor.*

*Low emitters of VOCs

How do you assess the health of an urban forest ecosystem?

The tree cover, or tree canopy, in a community is the central measurement most often used to determine the condition of urban forests. The health of an urban ecosystem is much more complicated than the number of trees it has, but the tree cover is a good indicator because the health of the trees and the ecology of the area are directly related.

Tree canopy goals have been established for three zones within a metropolitan area. The three zones and recommended minimum canopy goals are:

Business Districts	15%
Urban Residential	25%
Suburban	50%

A community should strive to reach these canopy goals by zone. Because each community is different, zones will be of varying sizes. The goal is to achieve an overall coverage of 40 percent.

One of the reasons for tree cover is to mitigate the heat island effect. Today’s cities are “hot spots” on the landscape with average temperatures three to 10 degrees higher than the surrounding countryside. By transpiring water, altering windspeeds, shading surfaces, and modifying the storage and exchanges of heat among urban surfaces, trees affect local climate, and thereby influence thermal comfort and air quality.

Another reason for tree cover is energy conservation. Research has shown that the shade from three trees properly planted around a home can cut air conditioning costs by 20% or more. Tree arrangements that save energy provide shade primarily on east and west walls and roofs, and wind protection from the direction of prevailing winter winds. This reduces the amount of fossil fuel that must be burned. The burning of fossil fuel is the primary source of atmospheric carbon dioxide.

Trees are also important to stormwater management. Tree canopy reduces the velocity of falling rain, helps stormwater infiltrate into the soil, settles particulates, slows runoff and prevents erosion. Trees used as buffer zones along streams and high runoff areas such as streets, and parking lots, help protect water quality.

As cities grow, forests are usually cleared, the land graded, and paved. As a consequence, the number of trees that once grew there and the life processes supported by those forests are replaced by man-made ecosystems. The cutting of trees done for urban development differs from when trees are cut in a managed forest in that in a managed forest, the cut area is reforested so there will be a continuous supply of timber and the forest ecosystem is preserved. In order to provide for human needs and a strong economy, we must have growth. The key is learning to manage growth.

Managing Growth

Georgia has witnessed unprecedented growth the past three decades. The rapid pace of development has turned many farms and forests into super highways, housing and industrial developments, strip malls and mega-shopping centers. At the same time, this development has contributed to the decline of older cities, towns and suburbs. Some communities have responded with no growth or slow growth policies. These policies tend to scatter development which increases the vehicle miles driven, and traffic congestion by forcing people who work in the city to find housing elsewhere. As cities grow at the urban fringe, the inner city infrastructure is abandoned while new infrastructure is built to support the peripheral growth areas. As cities struggle to pay for these investments and their maintenance, support for necessary services declines. The lesson learned from this is to accommodate growth in ways that make sense, preserve the community, protect the environment and enhance the economy. This is known as "Smart Growth".

Smart growth changes the urban sprawl pattern of development to development that enhances existing communities, is compatible with the natural environment, uses tax dollars efficiently, and is profitable for private investment. Smart growth includes conserving natural resources, open space and sustainable habitats. Examples include using wetland systems to purify stormwater runoff before it discharges into a lake or leaving as many trees as absolutely possible in a development that can reasonably be expected to survive.

Leaving trees in a development has many ecological benefits such as improving water and air quality, wildlife habitat and reducing erosion. But in an urban environment quality of life benefits are equally important. Leaving trees in a development buffers noise, offers recreational opportunities, reduces energy costs, increases property values, increases a project's marketability, enhances a community's image and facilitates tourism. However, there are costs associated with protecting trees during construction. Some of these costs include time delays. Taking the time to incorporate trees into the building process and protect trees during construction can slow building and add to construction costs. Space provided for trees may directly affect the profitability of the project such as fewer parking spaces or house lots. When trees are damaged by construction, there may be additional costs for removal and replacement.

There are many site designs and construction techniques that can be used to protect trees during construction. An urban forester can help recommend methods to protect existing trees and analyze the affect of a “changed” landscape on individual species.

Tree Protection Techniques

The first step in protecting trees is to identify sensitive, unique or particularly valuable trees or areas on the site. Check the local zoning and tree ordinances to see what setbacks are required or what special historic trees or species may be there which require protection by the community. Select trees that have the best chance for survival given the changes that will be made to the site such as grading, paving, utilities, traffic, etc. It is better to select “tree stands or tree islands” rather than protecting individual trees scattered throughout a site.

Identify the critical root zone of the tree(s) related to its species, age, health, location, soil conditions and surrounding vegetation. Organize construction activities such as contractor parking, material storage, temporary field offices, debris bury pits, concrete washouts, etc. away from the trees to be protected. Sign these areas and install protective fencing to minimize disturbance in the critical root zone.

Tree roots are often tangled or fused with roots of other trees that are being cleared on construction sites. Removing trees adjacent to protection areas can damage the remaining trees by tearing and breaking these fused roots. To reduce this risk, dig a 2-foot deep trench outside the critical root zone to insure a clean cut of roots. The trenches can be backfilled with loose soil and mulch to encourage new root development for the protected trees.

Fertilize protected trees before construction begins with a slow-release nitrogen fertilizer to help the trees resist insects and diseases that result from site disturbance. Mulch trees with a 4-inch layer of wood chips throughout the critical root zone. Natural debris from clearing vegetation from the site can be used as mulch. Mulching is the single most important thing you can do to protect trees. Fertilize again after construction to help the tree recover its vigor if it has suffered damage. Be careful not to over-fertilize as this can be detrimental.

Prune trees, using proper techniques, to be protected before construction to improve clearance between trees and the proposed structure. Light pruning can improve the tree’s vigor. If a tree has been damaged by construction, avoid pruning live plant material as it can accelerate the tree’s decline.

Tunneling is an effective technique for installing utility lines that can minimize the impact on critical root systems. Boring equipment can push piping and conduit underneath the roots of trees and even through solid rock. Sometimes several utility lines can be placed in a larger trench rather than having separate lines for each utility.

Local ordinances can prevent pavement installation within the critical root zone of trees. This is the preferred technique. However, the use of porous materials such as interlocking blocks, bricks, hollow brick pavers filled with soil and planted with grass allows the natural exchange of gases, nutrients and water between the soil and the air to nourish the root systems. Site plans can illustrate the construction technique.

The greatest challenge for protecting trees on a construction site is grade change. Usually, the steeper the grade, the less overall area of disturbance there will be. Tight grade contours and terracing are techniques used to make slopes steeper and maintain stability. Retaining walls allow for a change in grade without any sloping but can damage remaining trees and change drainage patterns.

Land development and construction have major impacts on the urban forest and it is going to happen in a growing economy and with a growing population. By working with developers, local governments and citizens, urban development can be planned to reduce the negative environmental impact. Our trees can be maintained and replaced to provide adequate tree cover and preserve our quality of life.

Conclusion

Forests provide us with many products and, at the same time, a place to recreate and find spiritual renewal. It is no wonder that forest management is of concern to many people and that we continually find it the subject of public debate and media attention. With an increasing world population, pressure on our natural resources will become even greater. As we develop natural resource policy, it is imperative that rational discussion, ecological awareness, and scientific principles guide our deliberations.

This study guide is merely an introduction to the study of forest ecosystems. The questions for the Georgia Envirothon competition will be taken from this document. We hope it will adequately prepare you for this event and encourage you to pursue more natural resource management studies.

APPENDIX A


nationalatlas.gov
Where We Are
FOREST COVER TYPES
Western Forests
Eastern Forests
Forest Resources of the United States
Alaska Forests
Hawaii Forests
Puerto Rico Forests
RUSSIA
CANADA
BERING SEA
GULF OF ALASKA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
IOWA
The National Atlas of the United States of America

APPENDIX B

Scribner Log Rule Form Class 78
Volume by Number of Usable 16 Foot Logs

DBH	Number of Logs								
	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5
10	28	36	44	48	52				
11	38	49	60	67	74				
12	47	61	75	85	95	100	106		
13	58	76	94	107	120	128	136		
14	69	92	114	130	146	156	166		
15	82	109	136	157	178	192	206		
16	95	127	159	185	211	229	247	266	
17	109	146	184	215	246	268	289	311	
18	123	166	209	244	280	306	331	358	
19	140	190	240	281	322	352	382	414	
20	157	214	270	317	364	398	432	459	486
21	176	240	304	358	411	450	490	523	556
22	194	266	338	398	458	504	549	588	626
23	214	294	374	441	508	558	607	652	698

APPENDIX C

Current Environmental Supplemental Material Related to Forestry

"Energy will be one of the defining issues of this century. One thing is clear: the era of easy oil is over. What we all do next will determine how well we meet the energy needs of the entire world in this century and beyond."

David J. O'Reilly, Chairman & CEO
Chevron Corporation

Looking to the Forests for Energy

In 1880, wood was the main fuel used in the United States to power engines, cook with and heat homes. The U.S. population was less than 50 million and the nation was mostly agricultural. Today, our energy needs come from non-renewable sources mainly petroleum, coal and nuclear power plants. In 2006, the U.S. population reached 300 million with most people living in cities and less than 2% involved in agriculture. Oil and gas have been the most reliable and efficient energy on a global scale to fuel modern society. However, oil production has peaked in all oil-producing countries except the Middle East and we realize oil and gas are finite resources, which will become scarce and expensive.

What does peak oil production mean? It means demand exceeds production. Before humans started using oil for energy, Earth's total recoverable oil is estimated to be 2 trillion barrels. It took 125 years to use the first trillion barrels but with current rates of consumption, it will only take 30 years to use the second trillion. The world now consumes 2 barrels of oil for every barrel discovered and what little oil is being found comes from places that are tough to reach and consume more energy to extract.

Global oil demand has been increasing by 1.4 percent per year in spite of increased efficiency. Total growth of worldwide consumption by 2025 is expected to increase 40 percent with increased demand coming from China, India and Latin America. It is clear energy supplied by petroleum is not sustainable and there will need to be a transition to sustainable energy sources.

During this transition a number of energy alternatives will be considered and some developed on a large scale. Among these are biofuels, geothermal, hydroelectric, hydrogen fuel cell, nuclear, solar, wind and maybe some we have not yet discovered. All options need to:

- affordably meet energy demand,
- address environmental objectives regarding climate change, air and water quality and ethical use of the land,
- be reliable in the short and long term.

As in the past, supplying the energy needs of a nation and the world involve political and financial decisions with far-reaching social and economic consequences. There is much disagreement even among scientists over efficiencies, advantages and disadvantages of the various alternative renewable energy sources. There seems to be no one answer.

As in the past, forests are being considered as a source of biomass to produce energy in the form of biofuels. Advances in technology make this an efficient and viable option to meet part of our energy needs.

<u>Biofuels.</u> A biofuel is any fuel derived from biomass. Biomass is recently living organisms or their metabolic byproducts, such as manure from livestock. Biofuels, unlike petroleum, coal and nuclear fuels, are renewable energy sources. They can be manufactured from animal fat and a variety of plants including trees which are renewable resources meaning they can be replaced in a reasonable amount of time. Biologically produced biodiesel from processed animal fats and vegetable oils is readily available for diesel engines. Biologically produced alcohols, most commonly ethanol and methanol, and less commonly propanol and butanol are produced by the action of bacteria. Biofuels are less polluting than fossil fuels.

<u>Combustion.</u> The most commonly known form of energy released from wood is by burning. Many homes use firewood to heat or provide supplemental heat. Some forest-product manufacturing plants burn wood residue in steam boilers. The steam drives turbines that generate part of the energy required to run the plant. Some pulp mills use what is called “black liquor”, a lignin-rich residue left over when making paper as a source of heat and electricity. Wood chips and wood pellets fuel some factories, schools, prisons and some chicken houses in the United States and Canada.

Burning wood refuse as a biofuel is more widespread in Europe. The difference in Europe is that the plants are not using just on-site industrial residues for energy but their main source of biomass is wood from the harvest site. In the United States, treetops and limbs are considered “unmerchantable” and are left behind to biodegrade or are burned or chipped to speed up the process of returning nutrients to the soil.

<u>Utilizing tree waste.</u> Harvesting tree waste for fuel could help prevent catastrophic forest fires. Dry, woody debris left behind by loggers or natural disasters is kindling for wildfires. The USDA Forest Service and the National Fire Plan, a cooperative of several federal agencies, promote removal of woody biomass debris from forests to reduce the risk of wildfires. There are millions of tons of logging residues left on the forest floor annually that could be utilized to produce energy.

<u>Dedicated plantations.</u> The Department of Energy is looking into engineering fast-growing, air-cleansing hybrid poplars planted on surplus farmland and cultivated for the energy they can yield. Other agencies and institutions are also studying southern pines, willows, cottonwoods and palm trees for the production of cellulosic ethanol, another type of biofuel. Hybrid poplars can grow up to 70 feet and 12 inches in diameter in 6 years and yield 10 dry tons of biomass per acre, enough to make 1,000 gallons of ethanol

according to the Oakridge National Laboratory. The challenge in cellulosic ethanol is to remove the phenols and lignins in order to extract the fermentable sugars.

Two processing options are used to produce fermentable sugars from cellulosic biomass. One uses acid hydrolysis to break down the complex carbohydrates into simple sugars. An alternative method, enzymatic hydrolysis, uses pretreatment processes to first, reduce the size of the material to make it more accessible to hydrolysis, then uses enzymes to convert the cellulosic biomass to fermentable sugars. The final step involves microbial fermentation yielding ethanol and carbon dioxide.

In July, 2006 researchers announced a 30-fold reduction in the cost of enzymes needed to produce cellulosic ethanol. Pre-treatment is critical to making the enzymes work effectively. This could reduce the cost ten to eighteen cents per gallon.

<u>Ethanol.</u> Ethanol is the most commonly known of the biofuels. It is cleaner burning than petroleum fuels and is used as a petroleum fuel additive today. Brazil uses the most ethanol to power their flex-fuel automobiles. Most of the ethanol produced in Brazil comes from sugar cane. Ninety percent of the ethanol manufactured in the United States comes from corn. Other sources are needed. If the entire U.S. corn crop were converted to ethanol it would only supply 10 percent of the nation's fuel needs. Potential sources of ethanol and the potential estimated yield are listed on the following table.

Source	**Sugar Content**	**Ethanol Yield**
Sugar Beets	15 – 20 units	700 gal. per acre
Sugar Cane	10 – 15 units	600 gal. per acre (112 gal. per ton)
Sweet Sorghum	10 - 20 units	500 – 600 gal. per acre
Sweet Potatoes	10 - 15 units	600 gal. per acre
Watermelon	10 – 14 units	600 gal. per acre
Peaches	12 – 15 units	600 gal. per acre
Corn (4.5 tons per acre)		400 gal. per acre (88 gal. per ton).
Pearl Millet (1.5-2 tons per acre) drought tolerant, faster fermentation, higher quality		400 gal. per acre
Switchgrass (5 tons per acre)		400 gal. per acre (80 gal. per ton)

Hemp is another high yield cellulosic ethanol source but it is illegal to grow in the United States since 1970. Even though it has no intoxicating effects, it is in the same family as marijuana and cultivation is prohibited.

<u>Ethanol production.</u> To sustain a profitable ethanol production business of 50 million gallons a year from these agricultural crops, approximately 3,000 dry tons would be needed per day. This would require 200,000 acres of farmland (30 square miles) with a

30% land use producing 5 dry tons per acre. An ethanol plant would need to be located within 60 miles of the crops. The goal is to average 90 gallons of ethanol per dry ton by 2012.

Agricultural crops such as corn, wheat, soybeans, etc. that could be used for making ethanol require increased application of nitrogen fertilizer. Imports of nitrogen have increased 8-fold since 1960. The use of pesticides for these crops is also considerable and cultivation is labor intensive even with modern machinery. These are costs that must be considered. There is also the concern over what growing dedicated crops for ethanol will do to the commodities market and the world's supply of food.

An ethanol refinery producing 50 million gallons per year would require approximately 625,000 dry tons of wood or 1.25 million green tons. This is based on a conversion rate of 40 gallons of ethanol produced from each green ton of pine fiber or 80 gallons of ethanol produced from each dry ton. Forests can be grown specifically to support an energy facility such as an ethanol refinery or the forests can be managed for a variety of uses and products.

Pine forests dedicated to growing wood for ethanol production could sustainably produce 144 green tons within a 24 year forest rotation from planting to harvest, or an average growth of 6 tons per year. This would require 8,680 acres of pine stands to be harvested each year and a total of 208,320 acres of timberland with growing pines be available to support the refinery.

Pine forests will likely be managed on a longer rotation. A rotation is the time between harvests based on the end use of trees. Pines managed for lumber and plywood would require older and larger trees. In this case, small trees are removed from pine stands during commercial thinning operations at approximately age 15 and age 24, while the final crop of trees are harvested at a larger size and older age. The smaller trees thinned would total approximately 70 green tons and would be most economical to use for ethanol production. The average production of wood in small trees would be 2 green tons per year. Using the sustainable management of pine forests for a variety of products alternative, a 50-million gallon per year refinery would need 625,000 acres of pine timberland supporting its raw material needs.

During any given year, several thinning operations at ages 15 and 24, as well as final harvest operations, would occur on a small proportion of this timberland area. Also, many other products would be made from larger harvested trees.

Georgia's tree farms, top growers of Georgia pine, produce up to 18 million green tons of extra wood pulp each year according to the Georgia Forestry Commission, which could be available for ethanol production. Georgia could produce 700 million gallons of ethanol per year from this source with little infrastructure changes.

<u>Is ethanol energy efficient?</u> A USDA study released in 2004 found that ethanol may yield as much as 67% more energy than it takes to produce. Previous studies ranged any where

from a 1:24 energy gain to 34%. A more recent study completed in March, 2005 found that Ethanol produced from corn generates 35% more energy than it takes to produce. This study was conducted by Argonne National Laboratory, which is one of the US Department of Energy's largest research centers.

Ethanol is an oxygenate that helps gasoline burn more completely thereby reducing emissions. Ethanol reduces greenhouse gases 80 percent below gasoline. Many cities have been able to meet clean air standards by using 10 percent ethanol in gasoline blends. Ethanol plants emit less than 100 tons of pollutants per year. Compare this to the average sized power plant that emits 20,000 tons per year. The average car emits 6 tons per year.

Some countries and states have E85 available (85% ethanol and 15% gasoline) which costs about 10 percent less per gallon than regular unleaded. However, there is a loss of power in the vehicle and the miles per gallon is reduced by about 15%. To use E85, a vehicle needs different fuel injectors, steel rather than rubber gas lines, and cannot have a plastic gas tank as ethanol will eat through plastic. Flex-fuel vehicles are being manufactured in Latin America and U.S. auto companies now make one or more flex fuel models.

Disadvantages. Common concerns surrounding producing ethanol from crops such as corn, wheat, rice, sweet potatoes, etc. is it could create a food shortage and adversely affect two billion of the world's poorest people wanting to survive. Producing ethanol from wood typically used by paper mills could instead be used to make ethanol thus affecting the paper goods markets. Removing leftover bits of trees from the forest could deprive the soil of biodegraded nutrients, which might slow future reforestation efforts and increase erosion. There have been studies showing that regrowth of forests will not be slowed as long as some of the residues are left behind and in some areas it may be possible to return most of the nutrients in the form of ash to the harvest site.

History of Ethanol as a Biofuel

No discussion of biofuels is complete without at least a brief glimpse of history. Henry Ford designed his automobiles, beginning with the 1908 Model T, to use ethanol. In a statement to a New York Times reporter he said, "The fuel of the future is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust -- almost anything," he said. "There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years." Ford was so convinced that renewable resources were the key to the success of his automobiles that he built a plant in the Midwest to make ethanol and formed a partnership with Standard Oil to sell it in their distributing stations.

During the 1920's, ethanol was 25% of Standard Oil's sales in that area. With the growth of the petroleum industry, Standard Oil cast its future with fossil fuels and dissolved the ethanol partnership. Ford continued to promote the use of ethanol but the petroleum industry run by politically influential investors, convinced the automobile industry to manufacture gasoline only engines, ran campaigns against the use of ethanol and undercut the biofuels sales. By 1940, Ford's ethanol plant closed due to inability to compete with the low prices of petroleum.

Summary. U.S. gasoline consumption is 140 billion gallons per year. Over 60 percent is imported contributing significantly to the trade deficit. If this 60 percent could be met from renewable sources in this country, the money would benefit the U.S. economy and emissions would be greatly reduced. The potential production of ethanol in the United States would meet about a third of the current demand. Wind farms that feed cheap, renewable energy to the electrical grid could have cars running on wind energy at the gasoline equivalent of $1.00 per gallon. This would require shifting to gas-electric hybrid, plug-in vehicles over the next decade for short distance driving. Raising efficiency standards for vehicles would also help. If each person reduced their consumption of fossil fuels 5 percent it would be equivalent to finding another 6 million barrels of oil per day. Conservation counts.

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